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THE

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TABLE OF CONTENTS.

[No. 63. OCTOBER, 1904.]

	PAGE
Bye-Laws and List of Members	vii
Proceedings of the Mineralogical Society	xix
G. F. H. SMITH: An improved form of Three-Circle Goniometer. (With plate I.)	1
R. H. SOLLY: On various minerals (Anatase, &c.) from the Binnenthal	16
H. HILTON: The Gnomonic Net. (With plate II.)	18
G. T. PRIOR: On Teallite, a new sulphostannite of lead from Bolivia; and its relations to Franckeite and Cylindrite	21
L. FLETCHER: On various masses of meteoric iron reported to have been found in Great Namaqualand and the adjacent region	28
L. FLETCHER: Historical note relative to the meteoritic fragments labelled 'Cape of Good Hope' and 'Great Fish River'	37
L. FLETCHER: Note relative to the history of the mass of meteoric iron brought by Dr. F. P. Moreno from Caperr, Patagonia	41
L. J. SPENCER: Irregularly developed crystals of Zircon (sp. gr. 4·0) from Ceylon	43
G. F. H. SMITH: The construction and use of the Moriogram. (With plate III.)	49
M. FLETCHER: Note on cobaltiferous Mispickel from Sulitjelma, Norway	54
Obituaries, Notes	56

[No. 64. MAY, 1905.]

Proceedings of the Mineralogical Society	xxv
H. HARTLEY: A new device for separating minerals by means of heavy liquids	69
R. H. SOLLY: Some new minerals from the Binnenthal, Switzerland	72
G. F. H. SMITH: An improved form of Refractometer	83
J. W. EVANS: On some new forms of Quartz-wedge and their uses	87
J. CURRIE: Note on some new localities for Gyrolite and Tobermorite	93
C. R. LINDSEY: Note on the occurrence of Brookite in the Cleveland ironstone	96
H. HILTON: The construction of Crystallographic Projections	99
H. HILTON: Some applications of the Gnomonic Projection to Crystallography	104
H. H. THOMAS: On an Epidote from Inverness-shire	109
Reviews, Notes	115

Digitized by Google

[No. 65. MAY, 1906.]

PAGE
Proceedings of the Mineralogical Society xxxi
H. A. MIERS and J. CHEVALIER: On the crystallization of sodium nitrate. 123
J. CHEVALIER: On the crystallization of potash-alum 134
J. W. EVANS: The identity of the Amiantos or Karystian stone of the Ancients with Chrysotile 143
J. W. EVANS: Gnomonic Projections on two planes 149
J. W. EVANS: Determination of the optic axial angle of biaxial crystals in parallel polarized light 157
T. CROOK and B. M. JONES: Geikielite and the ferro-magnesium Titanates 160
G. T. PRIOR: Dundasite from North Wales 167
G. F. H. SMITH: Paratacamite, a new oxychloride of copper. With a chemical analysis by G. T. PRIOR 170
L. J. SPENCER: Phenacite and other minerals from German East Africa 178
R. H. SOLLY: Notes on some Binnenthal minerals (Ilmenite, Seligmannite, Marrite, &c.) 184
G. F. H. SMITH: On the method of minimum deviation for the determination of refractive indices. With a diagram (Plate IV) . 191
Notes 194

[No. 66. FEBRUARY, 1907.]

Proceedings of the Mineralogical Society xxxv
A. HUTCHINSON: The optical characters of Antimonite . . . 199
A. HUTCHINSON: The chemical composition of Lengenbachite . . 204
L. J. SPENCER: Note on 'Feather-ore': identity of 'Domingite' (='Warrenite') with Jamesonite 207
C. J. WOODWARD: Note on Gypsum crystals found lining a disused well at chemical works 211
C. O. TRECHMANN: Crystallography of Sartorite from Binn. (With Plate V.) 212
J. W. EVANS: Notes on skiodroms and isogyres 230
T. V. BARKER: On the regular growth of soluble salts on each other. 235
G. F. H. SMITH: Ilmenite from Jacupiranga, Brazil 258
H. HILTON: Note on the thirty-two classes of symmetry . . . 261
Obituaries (with portraits of S. L. Penfield, Plate VI, and R. P. Greg, Plate VII) 264
Review, Abstracts 275

[No. 67. SEPTEMBER, 1907.]

Proceedings of the Mineralogical Society xli
G. F. H. SMITH and G. T. PRIOR: Red silver minerals from the Binnenthal, Switzerland 283
L. J. SPENCER: Notes on some Bolivian minerals (Jamesonite, Andorite, Cassiterite, Tourmaline, &c.) 308
R. PEARCE: Cassiterite pseudomorphs from Bolivia 345

Digitized by Google

PAGE

A. RUSSELL: On the occurrence of Linarite and Caledonite in County Wicklow 348

A. RUSSELL: Note on the mines and minerals of the Silvermines district, Co. Tipperary 350

G. F. H. SMITH: A new model of Refractometer 354

J. W. EVANS: A simple arrangement and notation of the thirty-two classes of symmetry based on the symmetry of zone-axes . . 360

A. P. YOUNG: On a Serpentine-rock from the mass of the Tarnthaler-Köpfe, Tirol 365

B. J. HARRINGTON: Isomorphism as illustrated by certain varieties of Magnetite 373

G. S. BLAKE and G. F. H. SMITH: Baddeleyite from Ceylon . . 378

F. H. BUTLER: On the occurrence of silver ore in the Perran mine, Perran Uthnoe, Cornwall 385

H. L. BOWMAN: On Hamlinite from the Binnenthal, Switzerland . 389

L. J. SPENCER: A (fourth) list of new mineral names 394

Reviews, Notes 416

Index, Errata 420

Digitized by Google

DESCRIPTION OF PLATES.

		PAGE
Plate I.	Three-Circle Goniometer (G. F. H. Smith)	1
„ II.	The Gnomonic Net (H. Hilton)	18
„ III.	The Moriogram (G. F. H. Smith)	49
„ IV.	Refractive Index Diagram (G. F. H. Smith)	191
„ V.	Crystallography of Sartorite (C. O. Trechmann) . . .	229
„ VI.	Portrait of Samuel Lewis Penfield (1856-1906) . . .	264
„ VII.	Portrait of Robert Philips Greg (1826-1906) . . .	268

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THE MINERALOGICAL MAGAZINE

AND

JOURNAL OF

THE MINERALOGICAL SOCIETY.

No. 63. October, 1904. Vol. XIV.

An improved form of Three-Circle Goniometer.

(*With Plate I.*)

By G. F. Herbert Smith, M.A., F.G.S.

Assistant in the Mineral Department of the British Museum.

[Read June 10, 1902.]

In a previous paper[1] the author pointed out the advantages of a goniometer possessing three graduated circles, and described an instrument of this type which had resulted from the addition of a two-circle arrangement to an ordinary reflective goniometer with a single (horizontal) circle. As was remarked in that paper, the adapted instrument has unavoidably the disadvantage that measurements can be made through little more than a right angle in any particular zone, with the single exception of the zone of reference, without readjustment of the vertical and third circles. The zone may, indeed, be completed by measuring from the diametrically opposite pole in the zone of reference; but difficulties occasionally arise in practice, and it is convenient to be able to measure through at least two right angles round the free end of the crystal by rotation of the horizontal circle only. In a subsequent note[2] the author suggested a way of overcoming this difficulty; and in fulfilment of the hope therein expressed he describes in the present paper an instrument, in the construction of which the

[1] 'A three-circle goniometer,' Min. Mag., 1899, vol. xii, pp. 175–182; a translation appeared in Zeits. Kryst. Min., 1900, vol. xxxii, pp. 209–216.

[2] 'Preliminary note on an improved form of three-circle goniometer,' Min. Mag., 1901, vol. xiii, pp. 75–76.

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suggested improvements with some modifications have been incorporated. The instrument has been constructed for the British Museum by Messrs. Troughton & Simms, of London.

As regards the arrangement of the graduated circles there is in principle no change at all, and the alterations relate solely to the optical parts of the instrument. The *line of reference*, i.e., the line to which the face under observation is brought perpendicular, is reflected so as to be nearly at right angles to the ordinary position. Thus on rotation round the axis of the horizontal circle the axis of the vertical circle may coincide with the line of reference in two positions, and observations may be obtained of both the faces of the crystal which are at right angles to this axis; previously no observation was possible from the face next to the vertical circle.

In order to effect this change, an auto-collimating telescope was at first employed, and the direction of light bent by means of a reflecting prism placed before the object-glass. This arrangement, however, was found in practice to introduce several difficulties: the stray light reflected from the back of the object-glass caused a glare in the field of view which completely prevented observation of minute crystalline faces; further, accompanying the principal image of the object-slit were to be seen a series of 'ghosts,' i. e., the images due to multiple reflections at the crystal-face and the near face of the prism; lastly, the field of view of the telescope was not as large as is desirable. These difficulties were, indeed, to some extent overcome; but after some trial it was finally decided to use separate tubes for the telescope and collimator, lying alongside each other, and to replace the single glass-prism by two distinct mirrors, one for each tube. The use of separate reflectors secured greater facility of adjustment.

(*a*) *The principle of a goniometer with three graduated circles.*

The object of a three-circle goniometer is to bring any desired edge on the crystal without readjustment parallel to some arbitrary direction in space, and it may be effected in various ways: but undoubtedly in practice the most convenient method is to maintain the optical parts, and therefore the eye of the observer, in the same position and to assign all the motions to the part carrying the crystal. The crystals usually selected for measurement are small, and, their weight being inconsiderable, they are held rigidly by the wax during the course of the observations. In the case of a goniometer constructed for the measurement of large crystals and especially of crystals still in position on the matrix, it

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would be advisable to give two of the motions to the optical parts. In such an instrument the specimen would be rotated about an horizontal axis only, and the bearing cones of the axis would be relieved of unnecessary strain by means of a counterbalancing spring placed underneath the stage.

In the present instrument all the motions have been given to the crystal, and the goniometer possesses essentially three graduated circles arranged thus:—

A the horizontal circle, whose axis is vertical and fixed in space;

B the vertical circle, whose axis is movable in an horizontal plane; and

C the third circle, whose axis may assume any desired direction in space.

These circles must satisfy the following conditions:—

The axis of *A* must be at right angles to the line of reference;

The axis of *B* must be at right angles to that of *A*;

The axis of *C* must be at right angles to that of *B*, although inclinable at any angle to that of *A*; and finally

All three axes must pass through the same point, the *optical centre*, which must itself lie on the line of reference.

How these conditions may be fulfilled will be considered after the description of the instrument.

(*b*) *The construction of the instrument.*

The base of the goniometer is formed of a tripod resting on three levelling screws. Rigidly connected with it are the arms carrying the pair of microscopes used for reading the scale of the circle *A* and the pillar supporting the tubes of the telescope and collimator. The latter tubes lie within outer tubes, each of which is adjustable about a vertical axis and about an horizontal axis at right angles to the length of the corresponding tube by means of three screws, one pushing and two pulling, which operate on the fixed collar. The tubes themselves may revolve about, and be translated in the direction of, their length; they are held by means of tangent screws which grip the split ends of the outer tubes. A small reflecting prism is placed immediately outside the slit of the collimator to permit of illumination from the side.

At the ends of the telescope and collimator remote from the observer are two tubes carrying mirrors, which fit round, and may slide along, the optical tubes; the ends away from the mirrors are split and the two halves are fitted with tangent screws to permit of rigid clamping to the

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corresponding optical tubes. Each mirror has three adjustments: a revolution about the length of the tube containing it, a translation in this direction, and finally a small adjustment about a vertical hinge; the last movement being actuated by means of a screw working against a spring. The telescope-mirror is placed further away than the collimator-mirror, and its tube is cut away at the sides so as to permit the passage of light reflected from the latter mirror. The mirrors are composed of speculum-metal, which gives reflections comparable in brightness with those obtained from totally-reflecting glass-prisms and avoids the difficulty due to stray reflections or 'ghosts.' If the metal becomes tarnished, it is easily cleaned by means of cotton-wool dipped in a mixture of two parts of alcohol and one part of ammonia; methylated spirit is not suitable because of the film frequently left on evaporation.

The Signal.

On the top of the tube containing the telescope-mirror is a recess, which receives an achromatic lens when not in use. The lens is hinged about an horizontal axis, and a lever without the tube enables the observer to place it in front of the object-glass of the telescope, thus converting the latter into a microscope of low power for viewing the crystal under measurement. Another lens is carried on an arm, which is hinged on a slide movable along a bar placed on the top of the telescope-tube near the eyepiece, and may be placed in front of the eyepiece; in this way smaller magnification is obtained, and the crystal is visible when not accurately placed at the optical centre.

The cross-wires in the telescope are fixed in position. Three eyepieces of varying powers are provided for viewing the reflected image. The type of signal employed (see fig.) differs slightly from that in ordinary use, because the image has to be accurately placed with respect to the horizontal as well as with respect to the vertical wire. The width may be altered at will; but once set it should not be altered, since the zero-reading of the circle A is affected at the same time.

The circle A has a diameter of 18 cm., approximately, and rotates about a vertical axis. Underneath its stage is a countervailing spring, by means of which the bearing surfaces of the cones may be relieved of as much of the superincumbent weight as may be desired. Inside the plate, on the bevelled edge of which the circle A is graduated, is another cone, larger in diameter but shorter in length, which is rigidly connected with the thick plate which carries the remaining circles and

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their accessories. The latter portion of the instrument may thus be rotated independently of *A* and placed in any position at will with respect to it; a strong clamp is provided for holding the two plates firmly together when in their proper relative position. By means of this device, as will be explained below (p. 11), the zero-readings of *A* may be made very nearly 360° and 180°. The scale is divided to 10′ and is read by means of a pair of microscopes placed diametrically opposite each other. In the focal plane of each is a pair of spider-lines, whose distance apart is equal to the apparent width of the divisions on the scale; they are operated by a micrometer-screw. One revolution of the screw carries the spider-lines from one to the next division on the scale, and thus corresponds to an angle of 10′. Its head is divided into ten parts, each of which is subdivided into six intervals, which therefore correspond to tens of seconds; hence by estimation the circle may be read to single seconds of arc.

The arm carrying the circle *B* is firmly attached to the plate mentioned above, by means of four screws, on releasing which the whole piece may be adjusted by means of other screws either towards the axis of *A* or at right angles to this direction. The fixed limb, carrying a pair of microscopes for reading the scale of *B*, is attached to the arm by means of three adjusting screws. Each pair consists of a larger screw of low pitch operating on the arm, and of a smaller screw, passing through the former and holding the microscope-limb firmly against the blunt points of the larger screw. The adjustment is made by moving the larger screws through the desired amount; the smaller screws are then tightened. By this device the pull on the limb is direct and there is no tendency to twist. Both sets of screws have hexagonal heads and are turned by means of the spanners shown at the base of the instrument (Plate I). The scale is 11 cm., approximately, in diameter, and is read in the same way as that of *A* by means of a pair of microscopes to 10″ directly, and to single seconds of arc by estimation.

To prevent excessive wear of the lower half of the fixed cone of the circle *B* owing to the weight bearing on it, two pairs of friction wheels are provided: one pair lies on the fixed limb between it and the circle, and is operated by means of a single balanced spring, to assure the pressure being always vertical; the other pair, visible in the picture, lies near the counterpoise and is operated by an adjustable spring. By means of pins passing through the fixed limb the former pair may be held out of the way, whilst the circle *B* is being placed in position, after removal for the cleaning of the bearings or some other purpose. The pin,

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on which the spring of this pair is pivoted, projects through the fixed limb, and may be raised, if it is found desirable to increase the countervailing pressure on the movable cone.

The arm, carrying the circle C, and the inside cone of the circle B are formed of a single casting to ensure the greatest possible rigidity. The latter circle is firmly attached to the arm, and the relative positions of the circle and the arm cannot, therefore, be altered, as is the case with the horizontal circle and the corresponding plate, for the purpose of making the zero-reading of the scale of B some convenient quantity. It has, however, been arranged that this reading should be approximately 180°, or 360° (depending on the microscope used), and it can be made almost exactly so by moving the microscopes; for this purpose the holes, through which pass the screws holding the microscopes to the fixed limb of the circle B, have been slotted.

The circle C is read to minutes of arc by means of a pair of oppositely placed verniers; greater refinement is unnecessary because more exact measurements may be made by means of the circle A. The fixed limb, carrying the verniers, is attached to the arm by means of three pairs of adjusting screws as before. Its scale has a diameter of 9 cm., approximately, and the cones taper towards the crystal-holder, since this is the usual tendency of the weight.

All three circles have the ordinary type of clamp and slow motion. The crystal-holder too is of the usual form, and possesses all the adjustments required. The rods, on which the crystals to be measured are fixed, are grooved down their length, so that any rod may be removed from the goniometer and set up again in very nearly the same position.

Counterpoises are provided to maintain the pressures evenly on the bearing cones of the circles A and B; that balancing the third circle C and the crystal-holder has been placed on the other side of the circle B, any shear on the cones of the circle B being thus obviated.

The mirrored axes of the telescope and collimator are inclined to each other at an angle of 22°, approximately. The greatest possible rotation about the axis of A is 240°, approximately; the axis of B can make with the line of reference angles of 57° towards the telescope and 3° towards the collimator respectively. When B is next to the collimator and its axis coincides with the line of reference, the greatest rotation about its axis is 188°, approximately, the axis of C making with the vertical, angles of 53° and 135° towards the collimator and the circle A respectively; when B is on the other side, the greatest rotation is 200°, approximately, the axis of C making the same angle towards the circle

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A, but an angle of 65° towards the telescope. The last angle might with advantage be made at least 90°, which, indeed, was the original arrangement before the alteration of the optical parts, by placing the tubes of the telescope and collimator closer together.

The tripod, main stage, and the circles are constructed of gun-metal; for the arm carrying the circle *C* and for the microscope-arms phosphor-bronze has been used; and the central rod of the crystal-holder is made of steel.

(*c*) *The adjustments.*

We may now consider the method of effecting the necessary adjustments.

To adjust the line of reference perpendicular to the axis of *A*, it is convenient, though in this type alone of goniometers not necessary, to use a plate of glass, the sides of which are accurately parallel. Such plates are supplied with goniometers by the makers and are as a rule correct enough for the purpose; nevertheless this has always been the weak point of the adjustments of such instruments, because the parallelism of the plate has to be assumed and is beyond the control of the observer.

Although not essential, it is convenient to have the mirrored axes of the telescope and collimator, and not merely the line of reference which bisects their acute angle, at right angles to the axis of *A*. The adjustment is effected in the usual way. The parallel-sided glass-plate is mounted on the crystal-holder, and adjusted as accurately as the eye can judge so that its plane is parallel to the axis of *A*. Care must be taken that the circle *B* is in such a position that a semi-revolution about the axis of *A* is possible. A glass-plate, the sides of which need not be parallel or even plane—a microscope-slide serves the purpose well enough—since no serious error is thereby introduced, is held in such a position in front of the eyepiece that light from the source of illumination is reflected down the tube of the telescope; the object being to illuminate the cross-wires and thus to see their images derived by reflection from the glass-plate. The images are not at first easily seen because of the confusion caused by the brilliant images of the source of illumination obtained by reflection from the surfaces of the various lenses in the telescope; and it is, therefore, convenient to use for the first rough adjustment the image of this source obtained by reflection from the plate; it is easily distinguished from the other images by being fainter and by moving with the plate. This image serves as a useful

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indicator for the images of the cross-wires, which may be seen after a little manipulation of the plate reflecting light down the tube. It may be remarked that, unless the cross-wires are set accurately in the focal plane of the telescope, their image thus derived will not come to focus in the same plane, and may, indeed, not be visible at all; this affords a test of the accuracy of the focusing of the telescope. The tube of the telescope-mirror is adjusted until the cross-wires and their images coincide. Rotating the plate through a semi-revolution about the axis of A, we view the images obtained by reflection from the other side of the plate: whatever be the interval separating the horizontal wire from its image, the plate must be adjusted through one half and the telescope-mirror through the other half. Turning back to the other side of the glass-plate, we repeat the adjustment. The agreement is soon made satisfactory.

The next step is to adjust the mirror of the collimator until the image of the signal, when in the centre of the field, is bisected by the horizontal wire. It may happen that on rotation about the axis of A the centre of the image does not traverse the horizontal wire, or in other words the mirrored wire is not perpendicular to this axis: we must rotate the tube of the telescope and at the same time the mirror-tube through the same angle in the opposite sense until the adjustment is effected. A similar adjustment must be made in the case of the collimator, should the image not be upright.

To adjust the axis of B perpendicular to that of A, we retain the glass-plate in the same position as before, and rotate it about the axis of C, until it is roughly at right angles to that of B: then we clamp C. By means of the crystal-adjustments and the slow-motion of C we set the plate in such a position that on rotation about the axis of B there is no movement of the image of the signal. For this adjustment we require at least a semi-revolution about the axis of B. We now adjust the axis of B with respect to that of A by means of the screws provided for the purpose until the image is exactly bisected by the horizontal wire.

The axis of C may be adjusted perpendicular to that of B in precisely the same way: the axis of B is rotated about that of A until it makes a right angle with its former position, and a side of the plate is brought exactly perpendicular to the axis of C, so that there is no movement of the image obtained by reflection from it. The axis of C is now adjusted until the image is bisected by the vertical wire; if at the same time it is bisected by the horizontal wire, the reading of B gives us the horizontal position of the axis of C. An equally effective and, since we

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may retain the glass-plate in its initial position, more convenient method is to make the axis of C coincide with that of A. Then since the latter is perpendicular to that of B, so must the former be. Keeping the axis of B in coincidence with the line of reference, we rotate the glass-plate about the axis of C. The images from the two sides will probably not both be bisected by the horizontal wire. By means of the crystal-adjustment make one lie as far above as the other is below; then by means of the adjustment of C adjust the axis until one image, and concurrently the other, is symmetrically set with respect to the horizontal wire. Rotating round the axis of A through a right angle and finding the reading of B when the image is set on the same wire, we obtain the zero-reading of B, i. e., the reading corresponding to the vertical position of the axis of C. The great advantage of this method is that it enables the observer to check any adjustment of direction without altering the position of the glass-plate.

In the final adjustment, the parallelism of the glass-plate may be disregarded. As has been pointed out earlier in this paper (p. 2), the axis of B may be parallel to the line of reference, or, if correct in absolute position, may coincide with it, in two positions, the circle B lying first on one, and then on the other, side of the optical parts. In either position we may adjust accurately some plane surface, say a side of the glass-plate hitherto employed, perpendicular to the axis of this circle. It is clear then that, if the images in the two cases have been symmetrically set on the cross-wires, the corresponding planes have occupied exactly parallel positions. We now adjust the axis of B with respect to that of A until the two images are bisected by the horizontal wire.

To adjust the axis of C, we turn from one position to the other through a semi-revolution about the axis of A, and then rotate C also through a semi-revolution, so that the image obtained by reflection from the same side of the glass-plate as before is on the cross-wires: whatever be the interval separating the centre of the image from the horizontal wire, we adjust the plate through one half and the axis of C with respect to that of B through the other half. The accuracy of the adjustment is tested again in the initial position. Turning round the axis of A until that of B is at right angles to the line of reference, we rotate the glass-plate about the axes of B and C until the image is set symmetrically on the cross-wires. The axes of A and C, if correct in absolute position, now coincide; and if, clamping B in this position, we rotate about these axes so as to retain the image in the field of view, it should always be bisected by the horizontal wire.

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The axes of the three circles are now accurately placed as regards direction; and it only remains to adjust them in absolute position so that they pass through the same point, the optical centre, which must itself lie on the line of reference.

The glass-plate is replaced by a rod, sharpened to a point at the free end, and the telescope is converted into a microscope by means of the auxiliary lens which is placed before the object-glass. The point is raised or lowered until it is somewhere near the centre of the field, and adjusted until there is no shift on rotation about the axis of *A*. Should the point not lie on the vertical wire, the telescope must be adjusted accordingly by translation in the direction of its length; the final adjustment should be made by turning the mirror about its vertical hinge. Since it is impossible to make this translation without affecting the position of the line of reference, the needle-point should be brought beforehand just on to the horizontal wire, and after adjustment has been made, the point should be again set on the wire; with this precaution the readjustment of the line of reference required will be small.

We next raise or lower the needle-point until there is no shift on rotation about the axis of *B*. If the point now lies off the horizontal wire, we turn the collar containing the telescope-tube about its horizontal axis accordingly. If, when the axis of *B* is parallel to the line of reference, the point lies off the vertical wire, we release the screws holding the base of the arm carrying the circle *B*, and move its axis parallel to itself horizontally by means of the screws provided until the point is exactly on the vertical wire after the clamping screws of the base have been securely tightened; this adjustment may, if preferred, be effected by means of the two double-screws lying in an horizontal plane, which hold the fixed limb carrying the pair of microscopes firmly to the arm just mentioned.

The final step is to adjust the needle-point until there is no shift on rotation about the axis of *C*. If, on turning round the axis of *A* until that of *B* is at right angles to the mirrored axis of the telescope, we find that the point lies off the vertical wire, we again release the screws holding the base, and move the arm to or from the axis of *A* as may be required. If, again, when the axis of *B* is parallel to the mirrored axis of the telescope, the point lies off the vertical wire, we adjust the axis of *C* accordingly so that it moves towards that of *B*.

We have only to adjust the collimator in absolute position so that its mirrored axis passes through the optical centre. To do this, we adjust the glass-plate so that the image obtained by reflection from it lies sym-

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metrically on the cross-wires, and, removing the eye-piece, we glance down the tube of the telescope. A portion of a circular patch of light is seen, due to the reflection of the illuminated object-glass of the collimator. If we adjust the collimator until this patch lies symmetrically with regard to the object-glass of the telescope, we shall effect the adjustment with sufficient accuracy for the purpose.

We must make a final test of all the adjustments, and the goniometer is ready for use.

For convenience of discussion, the various adjustments have been taken in the above order; but in actual practice we should make the absolute adjustment immediately after the corresponding relative adjustment, and thus, as far as possible, avoid interference with adjustments already made.

(*d*) *The method of using the instrument.*

We must first determine the exact zero-readings of the circles *A* and *B*. It was pointed out above (p. 5) that the upper part of the instrument could be rotated about an interior cone independently of the circle *A*. Rotating, then, *A* until the microscope next the observer reads exactly 360°, we turn the upper part until the axis of *B* coincides with the line of reference and the circle *B* lies on the side of the crystal-holder remote from the optical parts and clamp the parts together. Whatever correction may now be found necessary will only be a few seconds. Next we find the position in which the axis of *C* is vertical, and move the microscopes provided for reading the scale of *B* until they read as nearly as possible 360° and 180° respectively. A small correction may be found necessary, but it will only amount to a few seconds.

To make the best use of the goniometer, we adjust the edge of some prominent zone, preferably one of symmetry, parallel to the axis of *C*. To effect this, the axis of *B* is brought into coincidence with the line of reference; at the same time the axis of *C* should be vertical, since in that position the images obtained by reflection from the faces of the zone, when in adjustment, will cross the field horizontally on rotation of this axis, and the adjustment is made with greater facility. The zone thus adjusted is termed the *zone of reference*. We rotate *C* and take the readings of this circle for every face in the zone of reference, the axis of *B* still coinciding with the line of reference. Each reading corresponds to the position in which the particular face is perpendicular to the axis of *B*, and hence on rotation about this axis that face always remains

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parallel to the same plane. The faces in the zone of reference may conveniently be termed *origins*. The readings of the circles A and B for any other face of the crystal give us, after any correction required has been made, the distance and azimuth measured from the origin and the zone of reference, respectively. If the zone under measurement does not intersect the zone of reference in an existing face, the reading of C, taken in conjunction with the readings already found for the origins which have been encountered, will give the position of the pole of intersection in the zone of reference. The circle C can be read to minutes only; more exact measurements may be made on the circle A, if the axis of C be maintained in the vertical position.

Having measured the zone of reference, we study the observations and note the symmetry possessed by the zone. From a face of symmetry, if there be one, as origin, we systematically measure the crystal, commencing with the zone of reference and gradually increasing the azimuthal angle. A few measurements will soon show what symmetry the crystal apparently possesses. If the zone initially selected for reference is not a principal zone on the crystal, it is best to readjust the crystal so as to make such a zone that of reference.

Having completed the measurement of the crystal, we plot the positions of the poles of the observed faces on a sheet of paper. Whether the stereographic or gnomonic projection be selected, the plane of the diagram should be at right angles to the edge of the zone of reference. In general work the former projection is the more suitable. The author has found the stereographic net[1] devised by Professor E. von Fedorow for petrological determination, to be of great service and to give satisfactory results. The net is placed on a sheet of paper and the positions of the various poles marked by pricking through the net. Revolving the net about its central point, we may place the zero-point on any other origin, and read off from the net the distance and azimuth of any face referred to this new origin. If the zonal relations are very complicated, the gnomonic projection may with advantage be employed. By means of the table[2] prepared by the author, the positions of the various poles may be readily determined on any scale that may be suitable to the purpose. The net[3] drawn by Mr. H. Hilton may be used in a similar way.

[1] 'Über die von Professor E. von Fedorow herausgegebenen stereographischen Netze,' Leipzig, Wilhelm Engelmann, 1897. Vide Zeits. Kryst. Min., 1896, vol. xxvi, p. 337.

[2] Min. Mag., 1903, vol. xiii, facing p. 320; and Zeits. Kryst. Min., 1904, vol. xxxix, facing p. 154.

[3] Min. Mag., 1904, vol. xiv, p. 18.

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The author has occasionally found it necessary to ascertain the co-ordinates of some face, when referred to an origin other than that from which it has been measured. In case it should not be worth while to remount the crystal, a glass mirror has been provided, circular in shape and swivelled about a diameter. The mirror, when used, is placed so that this diameter is as nearly as possible parallel to the axis of one of the cylindrical adjustments of the crystal-holder. The circles *A* and *B* are set to the known distance and azimuth (subject to any necessary zero-correction), and the mirror is turned about its own diameter and about the axis of *C* until the image, obtained by reflection from it, is symmetrically set on the cross-wires, the final adjustments being made by means of the crystal-adjustment and the slow-motion in the two cases. Rotating about the axis of *C* through the angular amount necessary to bring the new origin into the zero-position, we revolve the mirror about the axes of *A* and *B* until the image, obtained by reflection from it, is again symmetrically placed on the cross-wires, and from the readings of these circles determine directly the new distance and azimuth.

The above procedure is, of course, merely the solution of a spherical triangle, in which the two sides and the included angle are known. By means of the mirror it is possible to solve all cases with two exceptions; when the three sides or the three angles are known, a second mirror[1], inclinable at any desired angle to the first, is required.

The method of measuring crystals on this form of goniometer may be varied to suit the different cases that may arise. For example, in the case of an hexagonal crystal, in which the prism zone is well developed, we should select this zone for reference; but it would be simpler to take measurements from the basal face. To do this, we turn the axis of *C* round that of *B* until the former is at right angles to the axis of *A*. Then, clamping *B* and using the circles *A* and *C*, we derive from *A* the complements of the distances from the base and from *C* the azimuthal angles.

The measurement of twinned crystals is facilitated by the use of this form of goniometer; especially in those numerous cases, in which some one corresponding zone on the two individuals[2] is readily recognizable.

[1] Cf. E. von Fedorow, 'Universalgoniometer mit mehr als zwei Drehaxen und genaue graphische Rechnung,' Zeits. Kryst. Min., 1900, vol. xxxii, p. 481; and K. Stöckl, 'Das Fedorow'sche Universalgoniometer in der Construction von Fuess und die Anwendung dieses Instrumentes zur mechanischen Auflösung sphärischer Dreiecke,' Zeits. Kryst. Min., 1904, vol. xxxix, p. 42.

[2] Cf. Min. Mag., 1902, vol. xiii, p. 146; and Zeits. Kryst. Min. 1903, vol. xxxvii, p. 231.

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In such a case, we set up one individual in the usual way and measure it for the identification of the faces, employing for reference the zone which has been recognized; we then turn to the pole of intersection with the corresponding zone on the other individual, and take measurements of both individuals from this pole as origin. The corresponding faces on the two individuals are equally distant from this origin, and are, therefore, easily recognized. The pole of twinning (corresponding to either a face or a zone-axis) is distant a right angle from this origin and its azimuth is half either the obtuse or the acute angle between the zones. Probably only one of these positions is near a crystallographically possible pole, but any doubt is at once removed by a study of a projection of the poles.

Readings of the origin should be taken for each zone in case it has shifted at all from the zero-position. Should it not be correctly adjusted, its pole on the sphere of projection will describe a small circle about the pole of the axis of *B*, and the greatest error introduced in the value obtained for the distance of any other pole from it by neglecting the shift is the distance between the two poles mentioned. In the calculation of the crystallographical constants, it may be best to utilize measurements of distances only, because in this way we measure directly from one image to another and the chance of including errors of adjustment is reduced to a minimum.

The makers of the instrument, Messrs. Troughton & Simms, of London, have in its construction fully maintained the high standard of mechanical skill characteristic of their work, and the author is especially grateful to them for the interest they have taken in the development of the goniometer, and for their readiness to incur any trouble in overcoming the various difficulties that are inevitably encountered in the realization of a new form of instrument.

As some indication of the accuracy that may be expected of this goniometer, the solutions of two pairs of spherical triangles, in which the two sides and the included angle are known, are appended, and the results obtained by observation with the instrument in the manner described in the paper (p. 13) are compared with the computed values. The known sides of the triangles in each pair are identically the same, but the included angles are supplementary. The data have been selected at random, and are given to minutes only, because the scale of the third circle does not admit of greater refinement. Measurements are made in turn from both of the poles, in which the given sides meet the third

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(unknown) side, and thus two independent values are obtained for this side; any serious discrepancy between the two would point to some error in setting or in observation.

Given $\begin{cases} b & 74° 27' \\ c & 53\ 42 \\ A & 42\ 25 \end{cases}$ $\begin{cases} b & 74° 27' \\ c & 53\ 42 \\ A & 137\ 35 \end{cases}$

	Observed.	Calculated.	O.-C.	Observed.	Calculated.	O.-C.
a	42° 57′ 4″	42° 57′ 11″	−7″	114° 29′ 40″	114° 29′ 16″	24″
B	107 29 55	107 30 34	−39	45 33 57	45 33 58	−1
a	42 56 50	42 57 11	−21	114 29 25	114 29 16	9
C	52 55 0	52 55 10	−10	36 40 35	36 40 48	−13

Given $\begin{cases} b & 65° 7' \\ c & 35\ 25 \\ A & 55\ 11 \end{cases}$ $\begin{cases} b & 65° 7' \\ c & 35\ 25 \\ A & 124\ 49 \end{cases}$

	Observed.	Calculated.	O.-C.	Observed.	Calculated.	O.-C.
a	49° 58′ 22″	49° 58′ 44″	−22″	87° 33′ 22″	87° 32′ 59″	37″
B	103 27 4	103 27 41	−37	48 12 30	48 11 52	38
a	49 58 0	49 58 44	−44	87 32 50	87 32 59	−9
C	38 24 43	38 24 33	10	28 26 17	28 26 17	0

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On various minerals (Anatase, &c.), from the Binnenthal.

By R. H. Solly, M.A.

[Read November 17, 1903.]

Anatase.—Some very brilliant and highly modified crystals of a light brown colour were obtained from the Ofenhorn in 1903. The largest crystal measures nearly an inch across. The form {313} is largely developed; other forms present are {100}, {110}, {111}, {331}, {221}, {223}, {335}, {112}, {113}, {117}, and also a new {*h k l*} plane close to (110) and (221), which is probably (24.14.7). These crystals resemble Seligmann's fig. 8 [1].

In 1902 some much smaller, dark brown crystals of a different habit, with the form {117} largely developed, were obtained from another part of the Ofenhorn. They resemble Klein's fig. 8 [2]. Three new forms were observed, namely {553}, {35.3.5}, and {40.3.5}.

(110) : (553) = 13° 16′ (calculated), 13° 20′ (measured).

(35.3.5) in the zones [100, 335], [553, 532].

(40.3.5) „ „ [100, 335], [010, 801].

The other forms observed were {100}, {110}, {111}, {221}, {335}, {801}, {401}, {532}, and {313}, all of which are represented by only small faces.

Laumontite.—Simple greyish-white crystals, some 1½ inches long, were found for the first time on the Ofenhorn in September, 1903. The forms present are *m* (110), *e* (201), and *b* (010).

			Calculated.			Measured.
mm‴	...	...	93° 44′	...	...	93° 40′
m'e	...	...	66 30	...	...	66 15

Albite.—In August, 1903, I found a simple, well-developed crystal in the white dolomite at the Lengenbach quarry. I believe this to be the first time that albite has been noticed as occurring in dolomite. The forms present are: *c* {001}, *x* {$\bar{1}$01}, and *b* {010}, large; *m* {110} and *M* {1$\bar{1}$0}, small; and *f* {130}, narrow. On removal of a fragment the following measurements were obtained:—

			Calculated[1]			Measured.
cm	...	...	65° 17′	...	...	65° 10′
cb	...	...	86 24	...	...	86 20

[1] Zeits. Kryst. Min., 1886, vol. xi, p. 337.

[2] Neues Jahrb. Min., 1875, p. 337, plate XI.

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Hyalophane.—At the annual meeting of the Mineralogical Society in 1901, I exhibited some twinned crystals of hyalophane, twinned according to the Baveno law of orthoclase. In August, 1903, I found in the Lengenbach quarry two groups with crystals twinned according to the Carlsbad law of orthoclase :—

	Calculated. Baumhauer[1].	Measured. Solly.
$(001):(\bar{0}0\bar{1})$	51° 28′	51° 6′
$(\bar{1}01):(\bar{1}0\bar{1})$	48 22½	48 15

Three new forms were observed on some small, simple crystals, namely $\{380\}$, $\{\bar{2}12\}$, and $\{\bar{2}11\}$:—

	Calculated.	Measured.
$(010):(380)$	31° 41′	32° 0′
$(\bar{1}01):(\bar{2}12)$	14 8	14 3

The face $(\bar{2}11)$ lies in the zones $[\bar{1}01, \bar{1}10]$, $[010, \bar{2}01]$.

[1] Zeits. Kryst. Min., 1903, vol. xxxvii, p. 605.

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The Gnomonic Net.

(*With Plate II.*)

By HAROLD HILTON, M.A.

Fellow of Magdalen College, Oxford.

[Communicated by Professor Miers, and read February 2, 1904.]

MR. G. F. HERBERT SMITH[1] has pointed out the advantages of the gnomonic projection for some special crystallographic problems. It seems to me that much of the labour in drawing the projections could be saved by a device similar to that employed by Fedorow, Wulff, Penfield, &c., in drawing stereographic projections[2].

Corresponding to the 'stereographic net' described by these authors (which is the stereographic projection of lines of latitude and longitude on a plane through a line of longitude), we have the *gnomonic net*, which is the projection of the lines of latitude (l) and of longitude (m) on the tangent plane at the point whose latitude and longitude are zero. The lines m are parallel straight lines, the lines l are hyperbolae having double contact with each other at two fixed imaginary points. The projection of a point whose longitude is μ and whose latitude is λ is the intersection of the lines $x = a \tan \mu$ and $y^2 \cot^2 \lambda - x^2 = a^2$ (taking suitable rectangular Cartesian axes through O, the centre of the net)[3].

It is not difficult (though rather tedious) to construct a gnomonic net; for the positions of the lines m and their intersections with the lines l are readily obtained by the help of the table given by Mr. Herbert Smith (loc. cit.). An intersection of $x = a \tan \mu$ and $y^2 \cot^2 \lambda - x^2 = a^2$ is the point ($a \tan \mu$, $a \sec \mu . \tan \lambda$), and these coordinates are given in the table for every degree from 0° to 65° inclusive. A net showing every other degree[4] is given (Plate II); this should be cut out and pasted on a drawing-board. It is surrounded with a protractor[5] showing every

[1] Min. Mag., 1903, vol. xiii, pp. 309–321.

[2] See, for instance, Zeits. Kryst. Min., 1902, vol. xxxvi, p. 14; Phil. Mag., 1903, ser. 6, vol. vi, p. 67.

[3] In the diagram a = 1.56 inches = 39.64 mm.

[4] As in the stereographic net given by Professor G. Wulff in plate II, Zeits. Kryst. Min., vol. xxxvi, which I have found useful.

[5] Unlike the stereographic net, the gnomonic net does not itself serve as a protractor.

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degree. The net is square, and the outer pair of lines m (separating the net from the protractor) correspond to a distance of 65° from the centre of the net[1]. The gnomonic projection of a crystal is drawn on tracing-cloth (or 'Pauspapier'), the centre of the projection being always placed over the centre (O) of the net.

The use of the gnomonic net is so similar to that of the stereographic net that I shall not describe it in detail; it is only necessary to take the account given by Professor G. Wulff[2] of the use of the stereographic net and to apply the necessary alterations. For instance, to find the projection of the pole of a given great circle, turn the tracing-cloth till the projection of the circle is parallel to the lines m and read off the position of the projection of its pole by means of the net. (The projections of a great circle and its pole are polar and pole with respect to the imaginary circle $x^2+y^2+a^2=0$.)[3] Similarly, given the projection of the pole we may find the projection of the corresponding great circle.

To change the plane of a gnomonic projection so that a point whose projection is P may become the centre of the projection, turn the tracing-cloth so that OP is perpendicular to the lines m, and move all points of the projection along the lines l through a distance corresponding to PO. It is best to mark the new positions of the points on another piece of tracing-cloth laid over the first (the net is readily seen through two pieces of good cloth).

To find the angle between two great circles whose projections are PQ and PR, change the plane of the projection so that P becomes the centre of the net and measure the angle between the new positions of the projections of the great circles; or else find the projection (h) of the great circle perpendicular to the two given great circles, produce PQ and PR to meet h in Q' and R', turn the tracing-cloth till h is parallel to the lines m, and read off the angle corresponding to $Q'R'$ on the net.

We can readily find by aid of the net the gnomonic projection of the poles of a crystal measured by means of a two-circle goniometer[4] on

[1] The corners of the net correspond to a distance of 71° 45′ from the centre.

[2] Zeits. Kryst. Min., 1902, vol. xxxvi, p. 15; cf. Phil. Mag., 1903, ser. 6, vol. vi, p. 68.

[3] If we project figures on a sphere from any point V on to any plane cutting the tangent cone from V to the sphere in the conic j, then all circles on the sphere project into conics having double contact with j. It follows that the tangents at the intersection of the projections of two orthogonal spherical curves are conjugate with respect to j. If V is on the sphere, j degenerates into a pair of points. In the projection shown in the diagram j is $x^2+y^2+a^2=0$.

[4] The method may also be applied to crystals measured with a one-circle goniometer,

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a plane parallel to the face through which the measured zones pass. We can then find (by the net) the projection of the poles on any other plane. The zones of the projection are then perpendicular to the orthographic projection of the crystal-edges on the same plane (as explained by Mr. Herbert Smith), so that the orthographic projection of the crystal can be readily drawn. It should be noticed, however, that we can find the directions of these edges by means of the stereographic net thus:—Find the stereographic projection on the same plane, and obtain the projections of the poles of the zones; the lines joining these points to the centre of the projection are parallel to the crystal-edges of the orthographic projection.

It should be noticed that the gnomonic projections of the poles of four cozonal faces form a range whose anharmonic ratio is that of the four faces[1]; hence, if we can find the projections of the poles, we can find the anharmonic ratio of the faces (by measuring the actual distances between the projections), even if we do not know the angles between the faces. This is useful sometimes when one of the projections is at infinity[2].

The gnomonic net may be used to solve graphically many problems in cartography or astronomy which can also be solved by the stereographic net. For example:—To graduate a sun-dial. Let P and Z be the gnomonic projections of the celestial north pole and zenith on the plane of the dial. (These points are readily found by means of the net when the position of the plane of the dial is given.) Produce PZ to cut the projection (h) of the celestial equator in R. Turn the projection till the line h is parallel to the lines m of the net, plot off points along h whose distances from R are 15°, 30°, 45°, 60°, &c.[3], and join these points to P; we thus get lines on the dial corresponding to each hour of local apparent solar time. The problem may also be solved (but not quite so readily) by the stereographic net or by the orthographic net (which is the orthographic projection of the lines of latitude and longitude on the plane of a line of longitude).

but the stereographic net is more convenient. This will be clear on a careful reading of Wulff, loc. cit., p. 16, problem 8.

[1] For the pencil of lines joining the poles of the faces to the centre of the sphere is cut by any plane in a range whose anharmonic ratio is that of the four faces.

[2] See Min. Mag., 1903, vol. xiii, p. 315.

[3] If we wished the dial to register apparent Greenwich time in longitude $d°$, we should take points whose distances from R are $(15 + d)°$, $(30 + d)°$, &c.

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On Teallite, a new sulphostannite of lead from Bolivia; and its relations to Franckeite and Cylindrite.

By G. T. Prior, M.A., F.G.S.
Assistant in the Mineral Department of the British Museum.

[Read February 2, 1904.]

AMONGST the specimens recently selected for the British Museum from the collection of South American minerals brought together by the late Theodor Hohmann, are two on which occurs a mineral in thin laminae resembling graphite. From the locality and associations, the mineral was at first presumed to be either franckeite or cylindrite, the two sulphantimonite-sulphostannates of lead from Bolivia, which were described in 1893 by Stelzner and Frenzel respectively[1]. Qualitative analysis, however, soon showed that, although similar to them in physical characters, it differed chemically from both franckeite and cylindrite in containing no antimony, but only lead, tin, and sulphur.

Of the two specimens from the Hohmann collection, one was labelled 'sulphoselenide of lead from Bolivia,' and the other 'selenide of lead from Atacama,' so that unfortunately the precise locality of the mineral is at present unknown. In all probability both specimens came from the same district in Bolivia, since in appearance they are very similar.

The new mineral occurs in thin graphite-like folia embedded in glistening kaolin, upon a dark grey matrix impregnated with iron-pyrites; on one specimen it is associated with a little wurtzite in thin plates, and on the other with a little galena.

Crystallographic Characters:—The teallite on the two specimens occurs for the most part in very thin folia with irregular boundaries. A few somewhat thicker plates, however, were found which had a nearly square outline and showed two zones of narrow faces replacing the edges. In each of these zones two sets of narrow pyramid-faces, making angles of 62½° and 75° with the broad cleavage-face, were measured on the three-circle goniometer[2]. Owing to the flexible nature of the plates, the measured angles differed rather widely—from 61° 42′ to

[1] Neues Jahrb. Min., 1893, vol. ii, pp. 114 and 125.

[2] For kind initiation into the manipulation of this instrument I am indebted to Mr. Herbert Smith.

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63° 16′, and from 74° 33′ to 75° 58′ respectively—and 62½° and 75° are taken as roughly the mean values. The angle between the two zones measured on the goniometer was 86°. The mineral is therefore in all probability orthorhombic, and not tetragonal as at first supposed. This result was supported by measurement of the angle between two sets of striae, which were observed on some of the plates, running parallel to the edges, and also by observation of the etched figures produced on the cleavage-face by dilute nitric acid. These consisted of two sets of fine striations, like the natural ones, parallel to the edges, and a third set equally inclined to them and occurring only in two opposite (obtuse) corners of the parallelogram formed by the nearly rectangular sets.

Forms observed:—

c {001}, a broad face showing two sets of striations inclined at angles of 86° and 94° and parallel to the intersections with the pyramid-planes.

o {111}, narrow faces often broken up and irregular owing to the cleavage.

p {221}, bright, narrow faces.

Other somewhat doubtful and imperfect narrow faces observed are: *a* (100), *d* (101), *e* (201), and *t′* (211).

Angles measured:—

	Measured.		Calculated.
c : *o* ...	62½° ...	...	—
c : *p* ...	75° ...	...	75° 25′
c : *a* ...	about 90° ...	...	90° 0′
c : *d* ...	„ 57° ...	...	54° 33′
c : *e* ...	„ 74° ...	...	70° 25′
c : *t′* ...	„ 79° ...	...	79° 39′

Angle between the zones [*co*] and [*co‴*] = 86° (i.e. (110):(1$\bar{1}$0) = 86°).

Crystal-system, orthorhombic. Axial ratios,

$$a : b : c = 0{\cdot}93 : 1 : 1{\cdot}31.$$

Crystallographically and in physical characters, teallite shows some relations with nagyagite in which *b* (010) is a perfect cleavage and *e* (101) : *e′* (10$\bar{1}$) = 88° 59½′; *b* (010) : *s* (343) = 75° 17½′.

Other Physical Characters:—Cleavage, *c* (001) perfect. Folia flexible, but not elastic. Hardness, 1–2. Teallite does not scratch gypsum, and is thus readily distinguished from franckeite and cylindrite, which scratch gypsum easily. Somewhat malleable, and makes a mark on paper. Like graphite and cylindrite it is difficult to pulverize. Specific

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gravity (weight of 1 cc.), 6·86. Lustre, metallic. Colour, blackish-grey. Opaque. Streak, black.

Chemical Composition:—The only impurity associated with the mineral was kaolin, a thin film of which was often found partially coating the cleavage surfaces. This was easily detachable, so that it was possible to obtain very pure material for analysis.

Heated in the closed tube, the mineral gives off a little sulphur and does not fuse. It is readily decomposed by hot, concentrated hydrochloric acid, as well as by nitric acid.

In the quantitative analysis the mineral was decomposed by fusion with sodium carbonate and sulphur, the tin being precipitated as sulphide from the aqueous extract, and the lead as sulphate from the nitric acid solution of the residue. The sulphur was estimated in a separate portion by fusing with sodium carbonate and nitre. The results of two analyses[1], I and II, were as follows:—

	I.	II.	Mean.	Atomic ratios.	Calculated for $PbSnS_2$.
Pb ...	53·00	52·95	52·98	0·256	53·05
Sn ...	30·89	29·89	30·39[2]	0·255	30·51
Fe ...	0·20	not det.	0·20	—	—
S ...	16·28	16·30	16·29	0·508	16·44
			99·86		100·00

The numbers obtained correspond very closely with the simple formula $PbSnS_2 = PbS{\cdot}SnS$.

The name *teallite* is given to the new mineral in honour of Dr. J. J. Harris Teall, F.R.S., Director-General of the Geological Survey of Great Britain and Ireland.

Relations of Teallite, Franckeite, and Cylindrite.

In view of the above results and the close similarity in physical characters between the new mineral and franckeite and cylindrite, it seemed desirable to make further analyses of the latter minerals in

[1] The atomic weights used throughout this paper are the 'International Atomic Weights' for 1904, with O = 16. Weights used in analyses, 0·6843 gram in I, and 0·3929 gram in II; for sulphur determinations, 0·2752 gram in I, and 0·2658 gram in II.

[2] In I the tin was determined as oxide by the direct ignition of the sulphide and is possibly a little too high; in II, in order to test for traces of antimony, the sulphide was converted into oxide by means of nitric acid and a slight loss may have occurred. The mean value given above is therefore probably not far from the truth.

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order to discover if any closer chemical relationship could be formulated between them and teallite than the mere fact that they all contained lead, tin, and sulphur.

Franckeite from Poopó, Bolivia.

Two specimens were analysed. One was selected as being the most crystalline and homogeneous, since it resembled teallite in showing thin plates with striae. In this case, measurement under the microscope showed that the striae were accurately at right angles and not at 86° or 94° as with teallite. Some of the plates also showed striae inclined at 45° to the rectangular sets, and on one plate occurred a narrow face inclined to the cleavage-face at an angle of 47° 46′. Crystallographically franckeite is probably very similar to teallite, but tetragonal instead of orthorhombic.

The franckeite on this specimen occurs as a vein about one inch in thickness in a porous quartz-rock impregnated with 'feather-ore': it was covered by a patch of brown wurtzite and blende with some iron-pyrites. In picking out material for analysis the chief impurity to be removed was the brown sulphide of zinc. No mechanically intermixed 'feather-ore' could be detected.

The mineral was decomposed by fusion with sodium carbonate and sulphur, as in the case of teallite. The mixed sulphides of tin and antimony were oxidized by nitric acid, and the resulting oxides weighed together: they were then separated by a double fusion with caustic soda. The result of the analysis of carefully selected material, consisting of thin plates, is given under III:—

	III[1].	Atomic ratios.	Calculated for $Pb_2FeSn_2Sb_2S_{14}$.
Pb	46·23	0·224	48·42
Fe	2·69	0·048	2·61
Zn	0·57	0·009	—
Ag	0·97	0·009	—
Sn	17·05	0·143	16·71
Sb	11·56	0·096	11·25
S	21·12	0·659	21·01
	100·19		100·00

Specific gravity (weight of 1 cc.) = 5·88.

[1] Weight used in analysis III, 0·5494 gram; for sulphur determination, 0·2179 gram.

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The numbers obtained correspond fairly closely to a formula $Pb_5FeSn_3Sb_2S_{14}$, which may be written $3PbSnS_2 + Pb_2FeSb_2S_6$, i. e. as a molecular compound of a sulphostannite of lead (teallite) with a sulphantimonate of lead and iron.

Another analysis was made on more massive material from a specimen of franckeite from the Trinacria mine, near Poopó. In this specimen no impurity of 'feather-ore' could be detected, but the material did not appear to be absolutely homogeneous, parts being readily cleavable into thin flakes, and parts less easily split up. The analysis was made on material consisting mainly of the more massive and less readily cleavable material, in order to see how it might vary in chemical composition from the more crystalline material used in the preceding analysis. The result of the analysis is given under IV, and that of Winkler's original analysis of franckeite, from Chocaya, Bolivia, under V:—

	IV[1].	Atomic ratios.	V. (Winkler.)	Calculated for $Pb_{4\frac{1}{2}}FeSn_{2\frac{1}{2}}Sb_2S_{13}$.
Pb ...	48·02	... 0·232	... 50·57	... 47·95
Fe ...	2·74	... 0·049	... 2·48	... 2·88
Ag ...	0·99	... 0·009	... Zn 1·22	... —
Sn ...	13·89	... 0·117	... 12·34	... 15·32
Sb ...	13·06	... 0·109	... 10·51	... 12·38
S ...	20·82	... 0·650	... 21·04	... 21·47
			Gangue 0·71	... —
	99·52		98·87	100·00

Sp. gr. ... 5·92.

The numbers obtained in this analysis approximate to a formula $Pb_{4\frac{1}{2}}FeSn_{2\frac{1}{2}}Sb_2S_{13} = 2\frac{1}{2}PbSnS_2 + Pb_2FeSb_2S_6$, midway between the formula $Pb_5Sn_2Sb_2S_{12}$ $(= 2PbSnS_2 + Pb_3Sb_2S_6)$ of Winkler and the formula $3PbSnS_2 + Pb_2FeSb_2S_6$ given by analysis III. The latter formula is taken as representing the chemical composition of the pure mineral, since the material used in the second analysis was less crystalline and apparently less homogeneous.

Cylindrite from Poopó, Bolivia.

Two specimens, consisting of well-defined cylinders made up of apparently quite homogeneous material, were analysed. The material

[1] Weight used in analysis IV, 0·7185 gram; for sulphur determination, 0·2557 gram.

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readily broke up into cleavage-flakes, showing a brilliant metallic lustre but no well-marked striations.

The results of these analyses[1] are given under VI and VII, while under VIII is added that of Frenzel's original analysis of cylindrite:—

	VI.	Atomic ratios.	VII.	Atomic ratios.	VIII. (Frenzel.)	Calculated for $Pb_3FeSn_4Sb_2S_{14}$.
Pb	35·24	0·170	34·58	0·167	35·41	33·70
Fe	2·81	0·050	2·77	0·050	3·00	3·03
Ag	0·50	0·005	0·28	0·003	0·62	—
Sn	25·65	0·215	25·10	0·211	26·37	25·85
Sb	12·31	0·102	12·98	0·108	8·73	13·05
S	23·83	0·743	23·88	0·745	24·50	24·37
	100·34		99·59		98·63	100·00
Sp. gr.	5·46	...	5·49	...	5·42	

The numbers agree fairly closely with the formula $Pb_3FeSn_4Sb_2S_{14}$, which may be written $3PbSnS_2 + SnFeSb_2S_5$, corresponding to the formula $3PbSnS_2 + Pb_2FeSb_2S_6$ of franckeite, with Sn in place of Pb_2.

The above formulae of franckeite and cylindrite, like most of those, not simply empirical, applied to minerals, admit of no real experimental proof; but it may be urged on their behalf that, without doing violence to the analytical results, they serve to suggest a chemical connexion corresponding to the close similarity in physical characters, not only between franckeite and cylindrite themselves, but also between these minerals and teallite.

As regards cylindrite, the close similarity, both in specific gravities and in the analytical results, of the three specimens at present analysed, appears to be good proof that the mineral which occurs in this peculiar cylindrical form has a definite chemical composition. In the case of franckeite the evidence on this point is not so conclusive. Owing to the mode of occurrence of this opaque mineral in radiated or spherulitic aggregates, it is difficult to be assured of its homogeneity. The results of the three analyses at present made certainly show variations in composition, though they all approximate to formulae which can be expressed as mixtures of $PbSnS_2$ with $Pb_2FeSb_2S_6$. The formula, $3PbSnS_2 + Pb_2FeSb_2S_6$, is adopted for franckeite as representing the chemical composition of material which had the appearance of being the most crystalline and homogeneous of the specimens in the British Museum collection.

[1] Weights used in analyses, 0·5684 gram in VI, and 0·6659 gram in VII; for sulphur determination, 0·2446 gram in VI, and 0·2289 gram in VII.

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Summary.

Characters of Teallite:—

Grey-black colour, metallic lustre, soils paper like graphite, occurs in flexible folia with nearly square outline, perfect basal cleavage, hardness, 1–2, does not scratch gypsum, density, 6·86. Orthorhombic, $a : b : c = 0{\cdot}93 : 1 : 1{\cdot}31$. Chemical formula, $PbSnS_2$.

Probable chemical formula of franckeite:—

$$Pb_5FeSn_3Sb_2S_{14} = 3PbSnS_2 + Pb_2FeSb_2S_6.$$

Probable chemical formula of cylindrite:—

$$Pb_3FeSn_4Sb_2S_{14} = 3PbSnS_2 + SnFeSb_2S_6.$$

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On various masses of meteoric iron reported to have been found in Great Namaqualand and the adjacent region.

By L. Fletcher, M.A., F.R.S.

Keeper of Minerals in the British Museum.

[Read March 22, 1904.]

The Balli Statement.

In November, 1886, Captain (afterwards Sir) James Edward Alexander was at Henkrees (29° S., 18° E.) on the southern side of the Orange River, South-West Africa, and sought for information as to what he might expect to find during his intended journey across Great Namaqualand. He says:—

'A respectable old Bastaard lived at Henkrees, Balli by name; he was the owner of a thousand head of cattle, of many horses and sheep. . . . He also told me of great quantities of copper far up the Great Fish River, and of hills from which malleable iron could be cut out[1].'

This report of Balli's statement, assuming that the accuracy of both report and statement can be relied upon, suggests the occurrence of embedded masses of meteoric iron far up the Great Fish River, at a locality which is hilly, and therefore different from the plain mentioned later by Alexander after his stay at Bethany in March and July, 1837.

The Hahn Statement.

According to a letter sent (1904) to the present writer by Miss M. Wilman, of the South African Museum, Cape Town, Dr. P. Daniel Hahn, of the South African College, Cape Town, was born at Bethany, and was the son of the Rev. Mr. Hahn, the Rhenish missionary at one time located there; he states that his father, when first living at Bethany, saw a great number of meteorites between that station and Berseba (Beersheba), and that the natives used the metal for the making of daggers and other objects.

Bethany is eight days' journey from Angra Pequena. Its mission station was started in 1820 by the Rev. Mr. Schmelen, but by reason of the fighting among the natives was abandoned by him three years after-

[1] 'An expedition of discovery into the interior of Africa, . . . ,' London, 1838, vol. i, pp. 144–145.

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wards: at the time of Alexander's journey (1837) the station was in ruins[1], and remained so until the Rev. Mr. Knudsen resumed missionary work there in 1843; the station had been abandoned by Mr. Knudsen a short time before the visit made by Andersson in 1852[2].

The Rev. Mr. Hahn referred to in Miss Milman's letter arrived at Bethany in February 1848. Frequent mention of Rev. Mr. Hahn [Rev. C. Hugo Hahn of Barmen (p. 149) and Rev. M. Hahn of Objimbingue (p. 250)] is made in Andersson's 'Notes of travel in South Africa' (London, 1875), and in other books written by the same author; the Rev. C. H. Hahn was not located at Bethany in 1848.

Immediately to the north of Bethany there is a plain, but east and south-east of it there are rugged hills or table-mountains extending to the Great Fish River[3]. Having regard to the physical features of the country between Bethany and Berseba, which is north-east of the former place, it will be seen that the account given by Dr. Hahn is consistent with that which had been given previously by Balli.

The statement recorded by Professor E. Cohen[4] that the Wild mass (to be mentioned later) is said to have lain on the mountains between Bethany and Berseba is doubtless merely a modified and particularized version of the above general account given by Dr. Hahn.

The Thies Statement.

Mr. C. Zerrenner, who prepared for publication (1860) the notes which had been made by the mining engineer, Mr. A. Thies, relative to a journey to the copper mines of Namaqualand, stated in a footnote (p. 53)[5]:—

'At this point of his notes, Mr. Thies intercalates the remark that he has found heavy masses of native iron (Tellur-Eisen), weighing from 450 to 1,000 lb., lying in the bed of the Fish River which rests on granite; he describes the iron as tough, of fibrous fracture, and suitable for being worked at any forge into any kind of tool.'

The name Fish River has been used by Sir J. E. Alexander[6],

[1] loc. cit., vol. i, p. 249.

[2] Andersson, 'Lake Ngami, . . .,' London, 1856, pp. 314, 347.

[3] Alexander, loc. cit., vol. i, pp. 238, 255; Schenck, Petermann's Mittheilungen, 1885, vol. xxxi, p. 134.

[4] Mittheil. aus dem naturw. Verein für Neu-Vorpommern und Rügen, 1900–1, 32 Jahrgang, p. 15; Annals of the South African Museum, 1900, vol. ii, part 2, p. 23.

[5] 'Reise des Ingenieurs A. Thies nach den Kupferbergwerken Namaqua-Land's in Süd-Afrika.' Berg- und hüttenmännische Zeitung, 1860, 19 Jahrgang, pp. 41–43, 53–54.

[6] e.g., loc. cit., vol. i, p. 236.

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and also on recent maps, as a substitute for Great Fish River, and Mr. Zerrenner used it in the same sense[1]. The above-mentioned statement must therefore relate to an earlier journey of Mr. Thies; for the journey recorded in the notes was entirely on the southern side of the Orange River, whereas the Great Fish River flows into the latter from the north. Masses of that size are not likely to have been transported to any great distance; for the total weight which can be safely carried in a Cape waggon is about 1,500 lb.[2]

There is no record of the part of the Fish River visited by Thies; the locality may be distinct both from the hills mentioned by Balli and Hahn, and from the plain mentioned in the following statement due to Alexander.

The Alexander Statement.

In the appendix to Sir J. E. Alexander's account of his journey into the interior of Africa (1836–7) is incorporated a short paper by Sir John Herschel containing the following statement[3]:—

'But what constitutes the peculiar and important feature of this discovery of Captain Alexander is the fact, stated by him, of the occurrence of masses of this native iron in abundance, scattered over the surface of a considerable tract of country.'

No particulars relative to the locality of the iron are given in the book, but in the accompanying map the words *much iron* are inscribed on the east side of the Great Fish River at 26° 5′ S., 18° 5′ E. This place being sixty miles distant from his route as marked on the map, Alexander himself cannot have seen the masses: this may also be inferred from a remark made in the paper which was communicated by him to the Royal Geographical Society of London in 1838[4]:—

'There is also *said to be* to the north-east of Bethany, near the Great Fish River, a plain covered with large masses of iron, some of which require several men to lift them. I have got specimens of this iron.'

The Andersson Statement.

Doubtless Mr. Charles John Andersson referred (1856) to the same group of masses in the following paragraph[5]:—

'At eight to ten days' journey with "ox waggon," east of the

[1] loc. cit., p. 41.

[2] F. Galton, 'Narrative of an explorer in Tropical South Africa,' New Edition, London, 1889, p. 14.

[3] loc. cit., vol. ii, p. 274.

[4] Journ. R. Geogr. Soc., 1838, vol. viii, p. 24.

[5] 'Lake Ngami, . . .,' London, 1856, p. 325.

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missionary station Bethany, meteoric iron is found in apparently inexhaustible quantities. I have seen lumps, of several hundredweights, brought from thence, so pure and malleable that the natives converted it into balls for their guns, &c., without any previous application of fire.'

In Andersson's map the words *iron found* are inscribed at 26° S., 19½° E., far to the east of the Great Fish River: but the above account suggests that up to that time he, like Alexander, had not visited the district where the masses were lying.

The Schenck Statement.

Dr. Adolf Schenck, who was at Bethany in 1885[1], was informed that the Alexander masses are on the left (i.e. east) bank of the Great Fish River, opposite Berseba; owing to the height of the water he was prevented from going to see them[2].

The Lion River Mass.

A mass of meteoric iron, weighing 178 lb. (81 kilos.), was brought to London in 1852 and purchased by Professor Tennant; it was reported[3] to have been 'found on a clay plain near Lion River in the close vicinity of one or more masses too heavy for transport: the removal of the present lump to the Cape by waggon, a distance of nearly 800 miles over the worst possible roads, being spoken of as attended with no small inconvenience. . . . The box contained several fragments of the clay forming the plain on which the mass was found. . . . The part cut has been done by the Namaquas for fabricating arrow-heads and assagais; the traces of two or three abortive attempts of cutting may also be seen in the surface of the mass.'

Lion, or Kamop, River[4] is a tributary of the Great Fish River, and is shown in Alexander's map at 27° S., 18° E.

The fact that the sender of the Lion River mass forwarded several fragments of the clay, forming the plain in which the mass had been found, shows that he himself regarded the mass as lying where it had fallen. Further, the immediate neighbourhood of one or more masses too heavy for transport to the Cape suggests that the smaller mass had

[1] Petermann's Mittheilungen, 1885, vol. xxxi, p. 182.

[2] Mittheil. aus dem naturw. Verein für Neu-Vorpommern und Rügen, 1900–1, 32 Jahrgang, p. 17.

[3] Amer. Journ. Sci., 1853, ser. 2, vol. xv, p. 1.

[4] Alexander, loc. cit., vol. i, pp. 219, 227.

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not itself been transported to the plain. But might not the plain mentioned by Alexander be regarded at Cape Town as being near Lion River? It seems more likely that this should be the case than that two groups of large masses should each be disposed on a plain, and the plains be within a hundred miles of each other, and nearly equidistant from Bethany.

The Wild Mass.

A large mass of meteoric iron, weighing 511 lb. (232 kilos.), has long been exhibited on a pedestal in the South African Museum, Cape Town. In the course of an inquiry into the history of various meteoritic masses, the present writer communicated twenty years ago (1884) with Mr. Roland Trimen, F.R.S., then the curator of the South African Museum, and was informed that 'the specimen in question is without further record than that it was found in Great Namaqualand (that is, north of the Orange River), and was sent to the Museum by Mr. Wild.' In December 1885, Miss Anderson Morshead, of Wiltshire, who had seen the mass at Cape Town and had promised the present writer to seek information from her friends in South Africa, was able to send him the following extract from a letter addressed by Mr. H. Piers, of Cape Colony, to Mrs. H. Reid, one of the daughters of the late Sir Thomas Maclear:—

'There is no record of the original site, only that some trader, finding it at a considerable distance in [Great] Namaqualand, brought it down to the Orange River, and left it on the other side. Long afterwards Mr. Wild brought it to Cape Town.'

Miss Anderson Morshead continued:—

'I asked Mr. Wild's daughter about the mass. Her recollection, as far as it went, was much the same as that of Mr. Piers. I think she believed the mass to have been found [at the Orange River] and sent down by her father (who merely defrayed the expense of transport) a year or so before 1862.'

This specification of the time as 'a year or so before 1862' rests upon hearsay, for Miss Wild was not then born; in the next edition (1886) of the British Museum Meteorite List, the year of the removal of the mass was recorded as 'about 1860.' The statement of Professor Cohen that the mass was lodged in the South African Museum in 1860 is doubtless an unintended variation of that record.

In a letter to Mrs. Mann (also a daughter of Sir Thomas Maclear, and sister of Vice-Admiral J. P. Maclear), Mr. Leo Layard furnished the following account given to him in England by his father, formerly curator

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of the South African Museum, and at that time (March 1899) too ill to write himself:—

'The large meteorite on the pedestal in the South African Museum was sold by the chief on whose land it fell to a trader for a barrel of rum; the trader took it some distance, and then pitched it out as being too heavy for his waggon. The chief then sold it again to two or three others, each of whom gave more rum for it and carried it a little way. Andersson was the last, and when he got it to Cape Town all the others claimed it, and threatened to go to law. Like sensible people they had a talk over the matter; and, coming to the conclusion that the lawyers alone would benefit by a lawsuit, they all agreed to give the meteorite to the Museum.'

As Mr. Layard, sen., in the same account confused the Victoria West meteorite with that of Cold Bokkeveld, it is possible that his memory was similarly at fault as regards the name Andersson, as might be expected after the lapse of nearly forty years; the name of Wild has long been painted on the pedestal supporting the mass. The true year of the removal to Cape Town becomes an important item in the investigation of the history of the transport and the tracing of the former locality.

It may be inferred from the statement published by Andersson in his work on Lake Ngami[1] that up to 1856 no such mass had been transported by him. In the latter part of that year, while at Cape Town, he was appointed superintendent of the Walfisch (Walfich) Bay Mining Company[2], of which the headquarters were at Objimbingue, Damaraland, and he retained the appointment for twelve months; in March 1858 he went on his voyage of exploration to the Okavango River, returning to Objimbingue a complete invalid at the end of 1859 or the beginning of 1860. After writing an account of his explorations he travelled to Cape Town, presumably by sea, not overland through Bethany. In 1861 he married at Cape Town, and after purchasing the large establishment of the Walfisch (Walfich) Bay Mining Company, settled down at Objimbingue as a trader[3], sending large troops of cattle and sheep overland through Bethany, and across the Orange River, for sale in Cape Colony[4]. It is therefore unlikely that he can have transported any large mass of iron from Great Namaqualand till after the date at which the Wild mass is said to have been brought

[1] loc cit., p. 325.
[2] 'Notes of travel in South Africa,' London, 1875, p. 333.
[3] loc. cit., p. 2.
[4] loc. cit., pp. 4, 334.

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to Cape Town. It follows from Andersson's account[1], and also from the above-mentioned letter of Mr. Layard, that the overland trade between Damaraland and Cape Colony was at that time in many hands: the particular journey mentioned in pp. 4–6 of the 'Notes of Travel' was made probably about 1863; no mass can have been bought from the angry chief at Bethany on that occasion. Galton points out[2] that C. J. Andersson 'must not be confounded with either of two subsequent travellers bearing the same or at least similar names.'

[*Addendum.* According to information sent on July 27, 1904, by Miss Wilman, the transport of the mass must have taken place before April 29, 1857; it has been ascertained that on the last-mentioned date a letter was addressed by Mr. Layard, from the South African Museum, to the Editors of the 'Cape Monthly Magazine[3]' which contains the following statement:—'the huge mass of nearly pure native iron from Namaqualand is exhibited by Mr. John Wild.']

The Mukerop Mass[4].

A mass weighing 392 lb. (178 kilos.) was met with in 1899 at Mukerop, in the district of Gibeon: 25½° S., 18½° E. No particulars of the finding of the mass have been recorded; the mass may have been transported to Mukerop, long before, by the Namaquas or the farmers.

Etched Figures of the Lion River, Mukerop, and Wild Masses.

From a study of the etched figures, Professor E. Cohen at first inferred that the characters of the Wild mass are distinct from those of the Lion River mass; but later, after examination of the Vienna specimen of the latter, he concluded that they are essentially identical: those of the Mukerop mass are likewise similar to the characters of both the Wild mass and the Lion River mass. The British Museum specimens of the three masses quite confirm this view, and leave no doubt that all belong to the same meteoritic fall. How far the dispersion of the masses has been natural, and how far it has been due to the Namaquas and the traders, it seems now impossible to ascertain.

The Springbok River Fragment.

A small fragment of meteoric iron was acquired by Dr. Krantz with the other minerals left by Dr. H. J. Burkart, who died at Bonn in 1874;

[1] loc. cit, pp. 4–5. [2] loc. cit., p. 193. [3] vol. i, pp. 319–320.
[4] Jahresh. des Vereins für vaterl. Naturkunde in Württemberg, 1902, vol. lviii, p. 292.

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thence it passed into the collection of Mr. J. R. Gregory, of London, and slices were afterwards distributed by him to various Museums. The only information relative to the history of the fragment is that given on the original label, namely, 'Meteoreisen, Springbock River, Cap d gut Hoffnung (*sic*), Afrika.' In Mr. Gregory's Catalogue, printed in 1889, the part retained by him is mentioned as 'Spring Bok River, Cape Colony, South Africa; small specimen (10 grams); structure very like Lion River.'

The original label gives no clue to the identity of the river, and Mr. Gregory's substitution of the words 'Cape Colony' for 'Cap d gut Hoffnung' rests merely on hypothesis.

The results of a study of the small slice preserved in the British Museum support Mr. Gregory's view as to the general resemblance of the etched figures to those of the Lion River mass; but the figures are distorted near the surface in such a way as to suggest that the specimen has been much hammered during the removal from a large mass. The piece may have been got from one of the Alexander masses, perhaps after transport.

As springboks are plentiful over a considerable part of South Africa, the name 'Springbok River' may have been locally given to various streams: Alexander remarked[1], for instance, that 'the hills about the Fish River abound in klip springer bucks'; Galton reported[2] that 'we passed one great herd of springboks that were migrating . . . It was by no means so numerous a herd as is often seen in Bechuana country; but the tufts of white hair on the backs of the males were as thickly scattered over the country as daisies on a lawn.' A place called Springbokfontein is in Little Namaqualand on an old line of travel from Bethany to Cape Town; another is at the extreme north of Great Namaqualand, due east of Rehoboth.

Nomenclature of the above-mentioned Masses.

Having regard to the probability, but still uncertainty, that these masses belong to a single meteoritic fall, which took place in some district comparatively near to Bethany, and to the desirability of preserving the history of slices taken from different masses, which after all may prove to be distinguishable by later research, it seems advisable not to confound them all under a single name Bethany, but to individualize the masses as Bethany (Lion River), Bethany (Wild), Bethany (Mukerop), and Bethany (Springbok River).

[1] loc. cit., vol. i, p. 239.

[2] loc. cit., p. 157.

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The Orange River district Mass.

The history of another mass of meteoric iron is very similar to that of the Lion River mass[1]:—

'A mass weighing 328 lb. (149 kilos.) was brought to London in August 1855 from the Cape of Good Hope by the master of a Scottish ship, to whom it had been entrusted by a farmer of the Orange River district, where the mass is supposed to have been recently discovered. It was taken directly to Professor Tennant.'

At the time of Alexander's journey Little Namaqualand was outside the boundary of Cape Colony, but 'a few missionaries had from time to time endeavoured to spread the truths of the Gospel in the district of the Orange River[2]'; this was the region north of the boundary and extending to the Orange River.

The etched surface of the Orange River district mass is entirely different in aspect from that which is common to the Wild, Mukerop, and Lion River masses; the lamellae are of medium, instead of small, breadth. The mass represents a different meteoritic fall; it may have been found in the Orange River district itself, and not transported thither as the Wild mass had been.

[1] Amer. Journ. Sci., 1856, ser. 2, vol. xxi, p. 213.
[2] Alexander, loc. cit., Introduction, p. x.

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Historical note relative to the meteoritic fragments labelled 'Cape of Good Hope' and 'Great Fish River.'

By L. Fletcher, M.A., F.R.S.
Keeper of Minerals in the British Museum.

[Read March 22, 1904.]

A SMALL specimen (weighing 20 grams), with a label carrying the inscription 'Meteoric Iron from the banks of the Great Fish River, South Africa,' was included in a mineral collection presented to the British Museum in 1873 by Mr. Benjamin Bright, of Bristol; the collection had been begun by Mr. Richard Bright (1754–1840), and increased by his son, Mr. Benjamin Heywood Bright (1787–1843), father of the donor. No lists or letters were handed over with the collection, and the history of the specimen and its label, prior to 1873, was thus unknown: as no additions to the collection seem to have been made by Mr. Benjamin Bright himself, the Great Fish River specimen had probably been acquired not later than 1843, the year in which his father had died.

The specimen has hitherto been regarded, by reason of its label, as part of the Great Fish River meteorite analysed by Sir John F. W. Herschel, and recorded in a paper entitled 'Notice of a chemical examination of a specimen of native iron from the East Bank of the Great Fish River,' which appeared in the Philosophical Magazine[1] for the year 1839, about the time when the specimen under consideration may have been acquired by Mr. Bright. The fragment examined by Sir J. Herschel, who was then living at the Cape of Good Hope, was one of several which had been given to Captain (afterwards Sir) J. E. Alexander during his journey through Great Namaqualand, perhaps when he was for the second time at Bethany in July, 1837[2]. As no other of the fragments appears to have been preserved, and the behaviour of a polished surface of the iron, on being etched, has not been placed on record, comparison of the characters of the Bright specimen with those of an authenticated Alexander fragment is impossible.

But it can be shown that specimens cut from an iron mass which had

[1] Ser. 3, vol. xiv, p. 82.
[2] Journ. R. Geogr. Soc. London, 1838, vol. viii, p. 24.

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been reported by Barrow[1] in 1801, and has long been known to collectors by the name of the Cape of Good Hope iron, may with reason, but inaccurately, have been labelled as 'from the banks of the Great Fish River' by a collector attempting to specify the part of the Colony of the Cape of Good Hope in which that iron mass had been found; the locality is, in fact, some hundreds of miles distant from the Cape from which the Colony itself, and thence the meteorite, had been given the name.

Barrow's statement is as follows:—

'Having recrossed the Great Fish River, we directed our course across a plain towards Graaff Reynet. On this plain was found some years ago, upon the surface of the ground, a mass of pure iron in a malleable state. Considered as a great curiosity, it was carried from place to place and is now in Cape Town. . . . It had probably been the thick part of a ship's anchor.'

The plain indicated by Barrow is about 33° 15′ S., 27° E., and on the western side of the Great Fish River; it does not extend to the bank of the river, but is at some distance therefrom. In 1804 von Dankelmann[2] was taken to the very spot by the son of the finder of the mass, and states that it is between the Sunday River and Bushman River, which are themselves both on the west of the Great Fish River. It is thus inaccurate to label a specimen of the Barrow iron as from the (bank or) banks of that river.

Professor Partsch[3], in 1843, assumed the Great Fish River mentioned by Captain Alexander to be identical with the long-known Great Fish River mentioned by Barrow, and was thus led to express the opinion that the masses recorded by the two explorers belong all to the same meteoritic fall; if such were the case, we should expect them to have identical characters. The etched surface of the Bright specimen is, in fact, indistinguishable from that of a specimen of the Barrow mass, although the kind of etched surface belongs to a rare type.

But on reference to the original work[4], it at once becomes manifest that the Great Fish River of Alexander is different from that of Barrow, and till 1837 had remained virtually unmapped: the locality of the iron masses in question is indicated in Alexander's map, from hearsay statements only, as being 26° 5′ S., 18° 5′ E.; the localities of the Barrow and

[1] J. Barrow, 'An account of travels into the interior of Southern Africa in the years 1797 and 1798,' London, 1801, vol. i, p. 225.

[2] Magazin für den neuesten Zustand der Naturkunde, von J. H. Voigt, 1805, vol. x, p. 12.

[3] 'Die Meteoriten . . . zu Wien,' 1843, p. 132.

[4] 'An Expedition of Discovery into the Interior of Africa (countries of the Great Namaquas, Boschmans, and Hill Damaras)': by Sir J. E. Alexander, London, 1838.

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Alexander masses are thus no less than 700 miles distant from each other, as the crow flies.

It is virtually certain that Alexander's book, in the appendix of which Sir John Herschel's paper was incorporated, was inaccessible at the time to Professor Partsch; indeed, the wording of the latter's statement, when critically examined, suggests that he was relying solely on such incomplete information as is given in the Philosophical Magazine reprint of Sir John Herschel's paper: in that reprint there is nothing to indicate that the Great Fish River mentioned therein is not the better-known one to which the name had been long applied.

Having regard to the rarity of the specimens belonging to this type of meteorite, and to the absence of reliable evidence of so wide a spreading of masses belonging to any meteor, the question arises as to whether the Bright specimen may not have been cut from the Barrow mass, and have no relation to Captain Alexander at all. That this is really the history of the specimen is rendered certain by the following considerations.

The London mineral dealer and author, James Sowerby (1757–1822), owned in the year 1806 a large piece of the Barrow mass; he figured and described it in his 'Exotic Mineralogy[1],' published in 1817:—

'Fig. 3 is my specimen of the iron found near the Great Fish River; it was obtained at the Cape of Good Hope and brought to England by Fichtel. (The piece brought to England formerly by General Prehn I understand was sent to Holland.) . . . These properties rendered it an excellent material for a sword blade, consequently upon his Majesty the Emperor of Russia visiting England I had a slice 2¾ inches long, 2 inches wide, and nearly ¾ inch thick, hammered at a low red heat into a blade 2 ft. long and 1½ inches wide—which, welded into a steel haft and mounted, I presented to his Majesty as a memorial of his visit. Previously to this a slice had been sawn off by Smithson Tennant. . . . The mass originally found was carried from place to place as a great curiosity; its weight was estimated by Barrow at about 300 lb.'

Probably Mr. Sowerby's piece was the only one from which collectors could obtain specimens of the Barrow iron by the method of purchase. According to Mr. Smithson Tennant[2], the piece was about 6 inches long, 4½ inches broad, and 2 inches thick.

After the death of Mr. James Sowerby in 1822, the business passed into the hands of his son, Mr. George Brettingham Sowerby (1788–1854). That the latter possessed some of the Barrow iron as late as 1842 is proved by the fact that a hammered lamina of it was purchased directly

[1] Vol. ii, p. 187.

[2] Tilloch's Philosophical Magazine, 1806, vol. xxv, p. 182.

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from him for the British Museum in October of that year; there was no label with the specimen, and no letters passed relative to the purchase: hence there is no evidence as to how Mr. G. B. Sowerby would have named the specimen. Mr. Charles Konig recorded, in the departmental archives, the purchase as being that of 'A laminated portion of the Cape meteoric iron of which a sword was made by Mr. Sowerby for the Emperor Alexander.'

And not long before, in 1840, a specimen had been acquired by Professor Partsch (through Mr. Bondi) from Mr. Heuland, of London, for the Vienna Collection. Professor Partsch adds:—

'It comes from the mineral collection of the late Mr. Sowerby, who possessed a large piece of the Cape Iron brought by Barrow [i. e. Fichtel] to England, and of which he had a sword forged for the Emperor Alexander of Russia.'

On comparison of the handwriting on the label of the Bright specimen with letters sent by Mr. G. B. Sowerby at various times to Mr. Konig, it becomes manifest that the label must have been written by him.

As the Alexander fragments were not then represented in the British Museum Collection, it is unlikely that Mr. G. B. Sowerby, if in possession of a specimen of the iron, would have disposed of it to a Bristol collector without first offering it in London. On the other hand, there is no evidence at all that Mr. Sowerby, or any other dealer, ever possessed one of the fragments brought back by Captain Alexander.

It may be added that the twelve other meteoritic specimens in the Bright Collection belonged all of them to falls well represented in 1843 in the British Museum and elsewhere, and that at least one of them (Red River) had been acquired from Mr. G. B. Sowerby.

All things considered, there can be no hesitation in concluding that the Great Fish River specimen in the Bright Collection had been acquired by Mr. Bright from Mr. G. B. Sowerby, and had been cut from the piece which Mr. James Sowerby had obtained from the Cape mass first recorded by Barrow: the label provided by Mr. G. B. Sowerby was doubtless based on the above-mentioned paragraph of his father's book.

It may also be inferred that the fragments brought back from Bethany by Captain Alexander were small bits, which had been broken from one or other of the masses, with the help of a hammer and chisel, and were suited rather for analytical than etching purposes; possibly they were fragments broken off by the Namaquas and intended for use as arrow-heads[1]: that examined by Sir J. Herschel weighed only 1·4 gram.

[1] Compare Amer. Journ. Sci., 1853, ser. 2, vol. xv, p. 1.

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Note relative to the history of the mass of meteoric iron brought by Dr. F. P. Moreno from Caperr, Patagonia.

By L. Fletcher, M.A., F.R.S.
Keeper of Minerals in the British Museum.

[Read March 22, 1904.]

THE mass of meteoric iron brought from Patagonia[1] in 1896 by Dr. Francisco P. Moreno, Founder and Director of the State Museum of La Plata, had been sought for by him, while exploring that region, because of a reference which had been made to it in Captain G. C. Musters's book, 'At Home with the Patagonians,' published in 1871.

Dr. Moreno believed the mass to be really identical with a block of supposed marble, referred to on page 87 of that work as having been seen by Captain Musters in 1869 at Amakaken, which is situated in longitude 71° 56′ W. and latitude 48° 10′ S.

As Dr. Moreno found the mass of iron not at Amakaken, but at longitude 70° 20′ W. and latitude 45° 15′ S., not far from the tribal encampment Caperr (Capperr or Capper), south of Rio Senguerr (or Senguer), there was great discrepancy as regards both the nature of the material and the position and name of the encampment or village; the discrepancy was thought to be a result of confusion of memoranda, or lapse of memory, on the part of Captain Musters, who died as long ago as 1879.

Caperr is indicated as *Capper* on the 'Plano preliminar y parcial de los territorios del Neuquen, Rio Negro, Chubut y Santa Cruz,' published in tomo ix, 1899, of the Revista del Museo de La Plata, dirigida por F. P. Moreno.

Through the courtesy of Professor Rodolfo Hauthal, of the Geological Section of the Museum of La Plata, my attention has been called to the following paragraph from page 101 of the book of Captain Musters, in which specific mention is made of a mass of iron heard of, not seen, by the author:—

'In the range of hills described as visible from Kaimak, there is

[1] Revista del Museo de La Plata, 1898, tomo viii, p. 305: plate 34 of the same volume gives a figure of the mass. Mineralogical Magazine, 1899, vol. xii, p. 167.

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a mine or vein of iron ore, about a mile due west from the brook, and marked by a large mass of white quartz. This is used by the Indians in the manufacture of bolas, and an excursion was made to it. We brought back numerous pieces, some of which, now in my possession, have been examined and pronounced to be brown and magnetic iron ore. The Indians also told me that some leagues to the east of this spot a mass of iron, having, as well as could be gathered from their account, the shape of a bar-shot, lies in the middle of a barren plain, and is regarded by them with superstitious awe. Whether this be an aerolite, or has any connection with the ore on the hill side, it was not in my power to determine, for in the critical state of feeling then prevalent, a visit of inspection was impracticable.'

Yaiken-Kaimak is shown in Musters's map at longitude 72° W. and latitude 45° 45′ S.: 'some leagues to the east of' Kaimak would thus agree satisfactorily with Dr. Moreno's statement of the locality where the iron-mass was found.

There can thus be no doubt that the block transported by Dr. Moreno is the one mentioned on page 101, not that mentioned on page 87, of the late Captain Musters's book.

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Irregularly developed crystals of Zircon (sp. gr. 4·0) from Ceylon.

By L. J. Spencer, M.A., F.G.S.
Assistant in the Mineral Department of the British Museum.

[Read March 22, 1904.]

SOME small isolated crystals from the gem-washings in Ceylon, recently sent by Mr. A. K. Coomáraswámy to the British Museum for determination and study, were at first thought to be rutile, but on detailed examination proved to be zircon of a rather unusual type. This has a specific gravity of 4·0, which is not increased when the crystals are heated.

The majority of the crystals are from the Balangoda district in the Sabaragamuwa province, and, according to Mr. Coomáraswámy[1], have been derived from a group of zircon-granites which occur in this district; a few others are from Walaweduwa in the Bamberabotuwa district, and from the Hatton district. Associated with them are zircons of more usual types (see p. 48); the present description is, however, confined to the crystals of lower specific gravity.

On placing the samples as received in molten silver-thallium nitrate with indicators of corundum (sp. gr. 4·0), almandine (4·1), willemite (4·15), rutile (4·2), and barytes (4·5), it was found that the specific gravity of the different crystals varied from 4·0 to over 4·5, the darker coloured crystals being less heavy and the lighter coloured more heavy. Only a few of the crystals have a specific gravity of exactly 4·0, these being of a dark brown colour and almost opaque. The majority are slightly heavier and show a transparent patch of a yellowish-brown colour on one side. As this lighter coloured portion increases in amount in the different crystals so does the specific gravity; and between 4·0 and about 4·2 there is an unbroken series.

The largest crystal (measuring $10 \times 5 \times 8$ mm. and weighing 0·592 gram) was found by hydrostatic weighing to have a specific gravity of 4·00; this crystal is in all portions of a dark brownish-black colour, and, except on thin edges, is opaque. Other, rather smaller, crystals were also separately weighed in water and found to have specific

[1] Geol. Mag., 1904, new ser., dec. 5, vol. i, p. 418.

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gravities of 4·02, 4·03, and 4·09 respectively; these all showed a lighter coloured and more transparent portion.

The crystals have an average size of half a centimetre across. Their hardness is 7. They are developed on all sides and only very rarely show any broken surfaces. Owing to the very irregular development of the crystals it was not at first easy to determine their symmetry, especially as the faces are somewhat rough and give only blurred images of the goniometer-signal. Further, zircon having in four zones [$ax = 31° 43'$, $xp = 29° 57'$, $pe = 28° 20'$] angles of nearly 30° and in three zones [$am = 45°$] [$mp = 47° 50'$] angles of 45° or nearly 45°, it was not

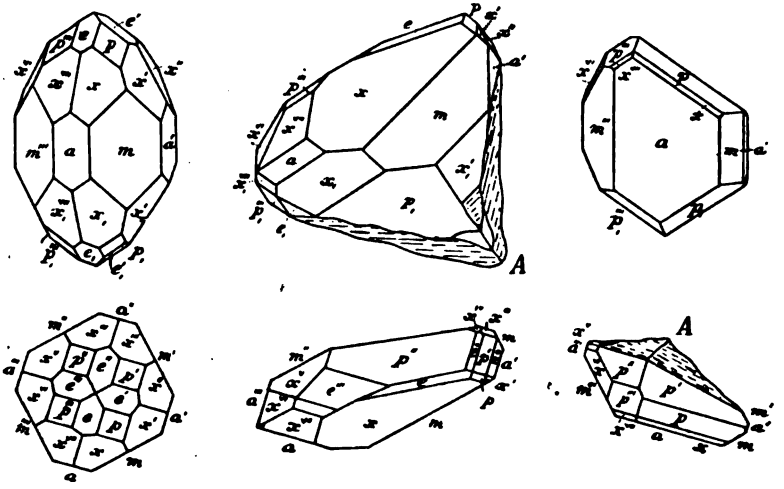

Fig. 1. Ideal development.

Fig. 2. Actual crystal.

Fig. 3. Actual crystal.

Zircon from Ceylon (Clinographic drawings and plans) [1].

always possible to distinguish the approximate measurements obtained from the angles of a cubic crystal, or to correctly orientate the crystals, until several zones on each had been measured.

The accompanying figures (figs. 2 and 3) are intended to give an idea of the shape of two of the crystals, while fig. 1 represents an ideally developed crystal with the same forms. The forms present are: a {100}, m {110}, e {101}, p {111}, and x {811}.

A peculiar feature presented by almost all the crystals of low specific

[1] The method of giving a plan of the crystal together with the clinographic drawing is borrowed from H. H. Robinson (Amer. Journ. Sci., 1901, ser. 4, vol. xii, p. 180).

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gravity is that on one side they show an area of deeply striated and stepped surfaces. These surfaces usually lie in the principal zones of the crystal, and meet in a central point (*A* in figs. 2 and 3) to form a pyramid, which in most crystals is quite flat and has its base parallel to *a* (100) or *m* (110). The zones in which they are most prominently developed are [100, 010], [100, 111], and [100, 1$\bar{1}$1], the low striated pyramid being then six-sided, as in fig. 3. (In the crystal here represented, however, one set of the striated surfaces is not quite in the zone [100, 111].)

At the centres, *A*, of these striated areas the crystals are pale yellow in colour, transparent, and possessed of a brilliant adamantine lustre. Away from this point the colour gradually shades off into brown, and the transparency and lustre diminish. The striated surfaces reflect long bands of images, but sometimes there are bright and smooth faces from which fairly good measurements, agreeing with the angles of zircon, could be obtained. On one crystal the centre of the area is occupied by a small projection having the form of a square pyramid bounded by (111), (11$\bar{1}$), (100), and (010).

The appearance presented by these striated areas is very similar to that shown by the individual crystals broken from a divergent group of crystals which have interfered with each other's growth. It would seem that several crystals had originally grown around a common centre, in which the points, *A*, of all the crystals coincided; the lighter and brighter striated surfaces would then have been the surfaces of contact between adjacent crystals; and the dull brown, freely-developed faces would represent the external boundaries of the whole group. The fact that the striated surfaces fall in the principal zones would further suggest that the crystals had some definite arrangement with respect to each other, and that the composite crystal was probably of the nature of a pseudo-symmetric or mimetic group. It is quite possible, however, that the crystals grew separately, and that their growth on one side was simply retarded by contact with some other body. The striated pyramidal portions of some of the crystals bear a striking resemblance to the so-called 'babel-quartz' from Beeralston in Devonshire, but they differ from this in having freely-developed faces on the opposite side.

When viewed through the prism-faces in parallel polarized light, the crystals extinguish uniformly parallel to the principal axis. Sections cut perpendicular to this axis are quite transparent and exhibit, in convergent polarized light, interesting variations in the optical characters.

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Two sections (sp. gr. 4·1) taken through both the dark and light coloured portions of one crystal (sp. gr. 4·02) showed a gradual transition from colourless through pale yellow to rich brown, the last predominating in amount. In the small colourless portion (which is at the tip *A* of the striated area of the crystal) the section is biaxial with a small axial angle ($2E = 8°$ about), the axial plane being perpendicular to the prism-face *a* (100) on the opposite side of the crystal; the birefringence is very strong and positive. On moving the plate so that the coloured portion gradually comes into the field, the axial angle gradually diminishes in size until the figure becomes strictly uniaxial (+); at the same time the numerous coloured rings gradually expand outwards and become further apart. On moving the plate still further in the same direction, the rings continue to expand and at last disappear; finally the black cross also disappears, and, in the darkest brown portion, the section is perfectly isotropic. The greater portion of the section is optically uniaxial with weak positive birefringence.

The section, although showing such wide differences in the strength of its double refraction, has about the same mean refractive index in all parts. This was determined, by focusing on the scratches on the two sides of the section, to be about 2·0[1]: the scratches on the under side remained in focus as the section was moved about on the stage of the microscope.

Three other sections cut from two small brown crystals (sp. gr. 4·0) on which there was none of the lighter coloured portion, showed by transmitted light a brown colour of varying depth in different parts. These sections were also, for the most part, optically uniaxial with weak positive birefringence; the strength of the double refraction, however, varied slightly in different parts and was sometimes almost zero; in one or two places in one section the figure was biaxial with a slight separation of the optic axes.

When heated to redness in the flame of a Bunsen burner, the crystals change in colour from dark brown to bright green, and become much more transparent and lustrous. No phosphorescence was observed, and there was practically no loss in weight. By immersion in silver-thallium nitrate, it was determined that the crystals of specific gravity 4·0 had the same specific gravity after ignition as before, but that crystals with a slightly greater specific gravity (up to 4·1) showed a slight increase (up to 4·2).

[1] The mean of ten approximate readings, varying between 1·9 and 2·1, was 1·97. The section has a thickness of about 1 mm.

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The sections after being heated to redness showed changes in their optical characters. The portions which were before brown are now green, and between crossed nicols, in parallel light, are doubly refracting with undulose extinction. In convergent polarized light the optic figures are confused and distorted, but positive biaxial figures with axial angles up to 20° and with axial planes of variable orientation can sometimes be distinguished. The birefringence is still low, though rather stronger than before. The small colourless portion in the sections of the first crystal remained, as before, biaxial with strong birefringence. The mean refractive index of the whole plate was also unchanged. When the crystals and sections were still more strongly heated over the bellows-blowpipe, no further change took place.

Absorption bands in the spectrum of light which had passed through the crystals were sometimes observed, but only after ignition.

The crystals described therefore consist mainly of a dark brown zircon of specific gravity 4·0, which is optically uniaxial with weak positive birefringence; when heated, this material changes to green in colour and becomes optically biaxial, but undergoes no change in specific gravity. Intergrown with this variety, in most crystals, there is a lighter coloured variety of zircon of higher specific gravity, which is biaxial with strong positive birefringence; this variety when heated increases in density, but shows no change in its optical characters. The two varieties are identical in crystalline form.

A chemical examination of one crystal of low specific gravity showed the presence of much silica and zirconia, and the absence of titanium. From a neutral solution containing the zirconium, oxalic acid threw down a bulky white precipitate which was very readily soluble in excess of oxalic acid; potassium zirconium sulphate was precipitated from a neutral sulphate solution; and a satisfactory colour was obtained with the turmeric-paper test for zirconium. Comparative tests were made with a red zircon from Expailly (sp. gr. 4·7), and the reactions were apparently the same for this as for the Ceylonese crystal. It is, however, quite possible, as suggested by Stevanović [1], that in one of these zircons there may be instead of zirconium another closely allied element.

From his own observations and from those of Professor A. H. Church [2], it has recently been pointed out by Dr. S. Stevanović [3] that zircons may

[1] Zeits. Kryst. Min., 1903, vol. xxxvii, p. 252.

[2] Journ. Chem. Soc. London, 1864, new ser., vol. ii, pp. 389, 415; Geol. Mag., 1875, new ser., dec. 2, vol. ii, p. 322; Chem. News, 1902, vol. lxxxv, p. 270.

[3] Zeits. Kryst. Min., 1903, vol. xxxvii, p. 247.

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be divided into three classes according to their different specific gravities and behaviour when heated, viz.:—

(i) Sp. gr. 4·0, both before and after ignition. (α-zircon.)

(ii) Sp. gr. 4·7, also unchanged by heating. (β-zircon.)

(iii) Sp. gr. between 4·0 and 4·7; when strongly heated the zircons of this class increase in density, reaching sometimes the higher limit.

The stable modifications of lower and higher specific gravity may be distinguished as α-zircon and β-zircon respectively. The former kind, to which the dark brown crystals described above belong, appears to have been noticed previously only twice. Church (1875) mentions a dark green stone of sp. gr. 4·02, which experienced no change in density when heated. Stevanović (1903) has described brown pebbles from Ceylon of sp. gr. 4·06, which showed a slight change from 4·02 to 3·965 when strongly heated; the colour at the same time passing to siskin-green and the transparency increasing: both before and after ignition the material was optically uniaxial with very feeble positive birefringence. The material described in the present note is thus very similar to that examined by Stevanović, though it shows some differences in the optical characters.

A zircon of low specific gravity is not necessarily α-zircon, for Damour[1] records a green stone from Ceylon which increased in density from 4·043 to 4·318 when heated; and Church (1902) mentions a green Ceylonese zircon which changed from 4·0 to 4·31. These belong to the third class, and may be inferred to consist of an intergrowth of α-zircon with an unstable modification (γ-zircon), which increases in specific gravity to 4·7 when heated. Specimens (all[2] of sp. gr. greater than 4·33) which increase in specific gravity to the higher limit (4·7) can contain no α-zircon, though they may consist of an intergrowth of β-zircon and γ-zircon. The fact that zircons of the third class frequently exhibit zonal structures amply supports the supposition of these intergrowths.

These variations in the specific gravity and optical characters of zircon give rise to many suggestions, but as Professor Church and others are still engaged on this work I merely offer the results of my determinative examination of the crystals described above as a contribution to this most interesting problem.

[1] Compt. Rend. Acad. Sci. Paris, 1864, vol. lviii, p. 158.

[2] The lowest recorded is by Stevanović (loc. cit., p. 250), who describes greenish crystal-fragments, from Ceylon, which increase in sp. gr. from 4·33 to 4·66, at the same time losing their colour and changing from optically biaxial to uniaxial.

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The construction and use of the Moriogram.

(*With Plate III.*)

By G. F. Herbert Smith, M.A., F.G.S.

Assistant in the Mineral Department of the British Museum.

[Read March 22, 1904.]

THE diagram (Plate III), to which for convenience the author has given the name moriogram[1], is intended to provide a method for rapidly determining the angles between a face of symmetry and all other faces with rational indices, which lie with it in some particular zone, when two of the angles are known, or, what is precisely the same thing, between a zone of symmetry and all other zones with rational indices, which intersect it in the same pair of opposite poles, when two of the angles are known: whenever possible it should be arranged that one of the known angles is a right angle. The moriogram may, therefore, be used in the course of computation for checking the accuracy of the work, or during the goniometrical measurement of a crystal for finding the relations subsisting between the faces or the zones.

The discussion—without, however, the loss of any generality—will be simplified if we consider a particular case, say that of the zone [*ab*], [100,010]. We will first suppose the angle *ab* (100 : 010) to be a right angle.

Let the angle *am* (100 : 110) be θ, then the angle between *a* (100) and any other face in the zone is $\tan^{-1} x$, where x is one of the values given by

$$x = y \tan \theta,$$

y being a simple whole number or a fraction composed of simple whole numbers.

If now we take x and y as Cartesian coordinates and assign to θ the values 0°, 1°, 2°, ... and so on, up to 90°, we obtain a pencil of rays emanating from the origin, each of which is inclined to its immediate neighbours at an angle of 1°.

We notice that, when $x = y$, $\tan \theta = 1$, and that therefore the unit distances on the two axes are equal. If the unit distance from the origin on the axis of Y be divided into rational parts, and lines be drawn through these points parallel to the axis of X, their intersections with the particular ray of the pencil in question give us at once the

[1] μόριον, a part.

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angles required. If the unit distance on the axis of X be divided so that the distance of any point from the origin represents the tangent of the corresponding angle, we may read off from the diagram the angles mentioned above. Lines drawn through the point on this axis representing any particular angle intersect the corresponding ray of the pencil in the line $y = 1$.

As yet we have merely considered fractions less than unity, that is to say the indices of faces lying between a (100) and m (110). Suppose, however, we write $\frac{1}{y}$ for y in the equation to the ray, we obtain

$$xy = \tan\theta,$$

i.e. a rectangular hyperbola, the asymptotes of which are the coordinate axes. This curve corresponds exactly to the ray and may be used in precisely the same way; the only difference is that the ratio of the indices has been inverted, and we now obtain the indices of faces lying between m (110) and b (010) without passing beyond the boundary $y = 1$.

In the same way we may see that the moriogram need not extend beyond the boundary $x = 1$. The effect of writing $\frac{1}{x}$ for x, which we remember represents the tangent of some angle, is to give us the cotangent of the same angle. The hyperbola now becomes the ray

$$x = y\cot\theta = y\tan(90^\circ - \theta),$$

which may be termed the complement of the previous ray.

Hence finally we perceive that the moriogram is bounded by a square, a side of which is the unit distance. A pencil of rays, one for every degree in the right angle, radiates from one corner, every fifth ray being drawn darker. Except in the case of the ray bisecting the right angle the intersections of the complementary rays with the opposite sides of the square are connected in pairs by rectangular hyperbolae, every fifth of which is also drawn darker. Traversing the moriogram are series of vertical and horizontal lines. The former lines cut the side which has above been termed the axis of X, such that the abscissae represent the tangents of some angle; again every fifth line is drawn darker. The horizontal lines divide the sides of the square at right angles to them into all fractional parts not involving numbers greater than 10. To avoid too great complexity, certain of the lines, namely those corresponding to the parts with the numbers 7 and 9 as denominators, have been drawn fainter. If the tenths of divisions be estimated we may read to 6′; but for most ordinary purposes accuracy to 30′ would be quite sufficient.

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It may be noted that the known angle need not necessarily be *am* (100 : 110); it may just as conveniently be the angle between *a* (100) and any other face—except, of course, *b* (010)—lying in the zone.

As an example of the use of the moriogram, the readings observed for the principal zones of cerussite are given and compared with the values obtained by calculation.

Three Principal Zones of Cerussite.

	Measured from (100).	
	Observed.	Calculated.
(530)	20° 5′	20° 6′
(110)	*	31 23
(350)	45 30	45 28½
(120)	50 40	50 39½
(130)	61 25	61 25½
(180)	78 20	78 25

	Measured from (001).	
	Observed.	Calculated.
(105)	13°15′	13°20′
(104)	16 25	16 30½
(103)	21 25	21 33½
(102)	30 35	30 39
(101)	*	49 51
(302)	60 45	60 39
(201)	67 15	67 7½

	Measured from (010).	
	Observed.	Calculated.
(0.10.1)	7°50′	7°52½′
(091)	8 35	8 44
(081)	9 55	9 48½
(071)	11 5	11 10½
(061)	13 0	12 59
(051)	15 25	15 27½
(041)	19 5	19 4½
(031)	24 40	24 45
(052)	28 55	28 57
(021)	34 35	34 40
(032)	42 40	42 41
(076)	49 50	49 51
(087)	50 25	50 26
(011)	*	54 8
(023)	64 15	64 16
(012)	70 10	70 7½
(013)	76 30	76 27
(016)	83 5	83 8

The moriogram may, though not so readily, be used in cases where no right angles are available. Thus suppose the angles *ab* (100 : 010) and *am* (100 : 110) are ψ_0 and ψ_1 respectively. The course of procedure may be seen from the following equations:—

$$\frac{\cot\psi_1 - \cot\psi_0}{y} = \frac{\cot\theta_1}{y} = \frac{1}{x} = \cot\theta = \cot\psi - \cot\psi_0.$$

Having found θ_1 we proceed in precisely the same way as before in the case where ψ_0 was a right angle, to find the values of θ corresponding to the indices of the faces in question.

The derivation of θ_1 from ψ_1 or of ψ from θ may be made graphically from the moriogram. The intercepts made on any vertical line by the

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rays of the pencil are, when measured from the axis of X, i. e. the lower side of the square, directly proportional to the cotangents of the corresponding angles. By means of dividers we can subtract $\cot\psi_0$ from $\cot\psi_1$. A convenient method is to use strips of paper divided on the edges exactly as the vertical lines in the moriogram corresponding to the angles 5°, 10°, 15°, 20°, 25°, 30°, 35°, 40°, 45°; or perhaps better still to use a square sheet cut slightly larger than the square boundary of the moriogram, the eight edges, four on either side, being divided as the lines mentioned, omitting the first. Selecting the most convenient of these lines, i. e. the one furthest from the origin which meets all the rays in question within the limits of the moriogram, we place the point marked 90° on one scale on that marked ψ_0 on the other, and convert immediately from θ to ψ, or vice versa. The author has found it on the whole more convenient to keep this conversion distinct from the moriogram itself, and employs the following method:—four scales of cotangents (cot 45° being represented by 20, 10, 5, and 2 cm. respectively) are drawn on a sheet of paper and four scales identical with the above are drawn, two on either side, on a strip of paper; the procedure is the same as before.

As an example the readings obtained for the zone [100,001] of epidote are added and compared with the computed values:—

Zone [100,001] *of Epidote.*

	Observed.		Calculated.	
	Moriogram.	Corrected.		
(301)	14°45′	16°45′	16°46′	Measured from (100).
(201)	21 40	25 55	25 57	
(302)	27 55	35 10	35 4½	
(403)	30 50	39 40	39 32	
(101)	38 25	51 40	51 41	
(304)	46 35	64 40	64 38½	
(203)	49 55	69 45	69 46	
(102)	57 50	81 0	81 2	
(103)	67 20	93 10	93 2	
(104)	72 30	99 1	99 0	
(001)	90 0	*	64 37	Measured from (100).
(105)	75 55	54 0	53 58	
(102)	57 50	42 15	42 6	
(101)	38 25	*	29 54	
(201)	21 40	18 15	18 25	
(301)	14 45	13 0	13 11	

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To draw the curves, their intercepts on every ray of the pencil were calculated, and the points thus determined were pricked off on the diagram. Since from the equation

$$xy = \tan\theta,$$

we have

$$\frac{dy}{dx} = -\frac{y}{x} = -\tan\phi = \tan(180° - \phi),$$

where $y = r\sin\phi$, $x = r\cos\phi$, r and ϕ being radial coordinates, we see that the tangents to the curves at all points lying on the same ray are parallel, and that the ray and any tangent make supplementary angles with the same coordinate axis. The curves were developed by means of the tangents. Their direction for points lying on the same ray were conveniently found by means of the form of protractor[1] devised by the author for plotting gnomonic projections, and they were drawn for each curve in succession by sliding the protractor along a straight-edge. Finally, for the inking of these curves the templates[2] devised by Professor R. H. Smith were employed.

[1] Min. Mag., 1903, vol. xiii, p. 313; Zeits. Kryst. Min., 1904, vol. xxxix, p. 146.

[2] Set of 'R. H. S. Curves,' by Professor Robert H. Smith, published by Cassell & Co., London.

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Note on cobaltiferous Mispickel from Sulitjelma, Norway.

By the Rev. MARK FLETCHER, M.A., F.G.S.

Vicar of North Sunderland; Lecturer in Mineralogy at the Durham College of Science, Newcastle-upon-Tyne.

[Read June 7, 1904.]

SOME months ago Professor Henry Louis presented to this college several isolated crystals which he had brought from the Sulitjelma (or Sulitelma) mines in Arctic Norway: they occur there in masses of copper-pyrites and iron-pyrites, for which this district has been famed for some years.

The crystals are of various sizes, ranging in length from 4 to 8 mm. They have a metallic lustre and silver-white colour. The fracture is uneven, and no cleavage is visible. On a freshly broken surface small yellow particles can be seen with the naked eye; these also have a metallic lustre, and are probably iron-pyrites, a probability which is strengthened by the appended chemical analysis. The specific gravity varies from 5·94 to 6·02, and the hardness is just under 5. The crystals are all of a pronounced rhombic aspect. Three of them were measured, and the forms present were found to be {011}, {012}, and {110}; the faces of the forms {011} and {012} are faintly striated parallel to their edges of intersection.

Two of the measured crystals are simple, and the third is a composite growth of two interpenetrant individuals. This latter approximates to a twin, of which the twin-plane is (210); but it is only approximation, the difference between the observed and calculated angles being too large to justify the recognition of a new twin-plane, especially as this relation of the individuals was only found in a single instance.

The means of the best readings of the angles of the simple crystals are the following:—

	Measured.	Calculated.
(011) : (01$\bar{1}$)	80° 0½′ ...	—
(011) : (012)	19 16½ ...	19°12½′
(012) : (0$\bar{1}$2)	61 37 ...	61 34
(110) : (1$\bar{1}$0)	69 6 ...	—

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From the above angles we derive the axial ratios:—

$$a : b : c = 0{\cdot}6886 : 1 : 1{\cdot}1915.$$

These axial ratios suggested that the specimens are crystals of glaucodote; but the following two analyses by Dr. J. A. Smythe, of the Durham College of Science, show that the material is mispickel, containing about one per cent. of cobalt and thus approaching to the variety known as danaite.

	I.	II.	Mean.	Atomic ratios.
S	21·76	21·96	21·86	0·683
As	42·20	42·15	42·18	0·562
Fe	35·31	36·17[1]	35·31	0·632
Co	1·32	0·98	1·15	0·020
	100·59	101·26	100·50	

The atomic ratios show an excess of iron (0·090) and a still greater excess of sulphur (0·121) over that required by the formula (Fe,Co)AsS; this is probably owing to the mechanical intermixture of iron-pyrites, yellow specks of which on the fractured surface are visible to the naked eye.

It remains to be mentioned that crystals of cobaltiferous mispickel (danaite) from Sulitjelma were described by Professor A. W. Stelzner in 1891[2]: these were a centimetre in length, showed the forms {110}, {011}, {012}, and contained 6·81 per cent. of cobalt.

[1] Dr. Smythe remarks that in the method adopted in the second analysis there was a risk of insufficient washing, so that the lower figure for the iron is likely to be the more correct.

[2] A. W. Stelzner, 'Die Sulitjelma-Gruben im nördlichen Norwegen. Nach älteren Berichten und eigenen Beobachtungen besprochen,' Freiberg (Saxony), 1891. Stelzner's results are quoted by J. H. L. Vogt in Zeits. prakt. Geol., 1894, p. 43; and in Hintze's 'Handbuch d. Mineralogie,' 1901, vol. i, p. 863.

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OBITUARIES.

Charles Alexander McMahon (1830–1904).

In Lieut.-General Charles Alexander McMahon, F.R.S., who died at his residence in Nevern Square, London, on February 21 last, our Society loses an earnest worker on the mineralogical side of geology. The son of Captain Alexander McMahon, of the East India Company's service, he was born at Highgate on March 23, 1830, and obtained his first commission, on February 4, 1847, in the 39th Madras Native Infantry, where he served for eight years. After this he became a member of the Madras Staff Corps, and was transferred to the Punjab Commission. Here he did admirable work for thirty years as Commissioner and Judge, gaining early a reputation for nerve and promptness in action. It was due to the latter that, at the outbreak of the Indian Mutiny—in May, 1857—just after he had taken charge of the Sialkot district, the revolted native troops were met and crushed by General Nicholson, then on the march to Delhi.

About the year 1871, McMahon, then Commissioner of Hissar, began to work at petrological questions, his first contribution, 'On the Blaine group and the central gneiss in the Simla Himalayas,' appearing in the 'Records of the Geological Survey of India' in 1877. In 1879, while on furlough in England, then a Lieutenant-Colonel, McMahon, with characteristic thoroughness, entered as a student at the Royal School of Mines, and attended the lectures by Professors Judd, Huxley, and Warington Smyth. The experience thus acquired was applied, on his return to India, to the thorough study of the crystalline rocks in the Himalayas, and he increased the two papers already published in the 'Survey Records' by nine others, in which he proved some gneisses to be igneous rocks, and their foliation due to movements prior to final consolidation.

After thirty-eight years' service he retired, but was promoted to Major-General in 1888 and Lieutenant-General in 1892, and he settled down in London to work steadily at his favourite studies, publishing papers in the 'Mineralogical Magazine,' the 'Geological Magazine,' the 'Proceedings of the Geologists' Association,' and the 'Quarterly Journal of the Geological Society.' The more notable in the last were on the crystalline rocks of the Lizard district, where his Indian experience stood him in good stead, and on the phenomena associated with the Dartmoor granites—though he did not lose touch with India, and

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co-operated with his son, Major A. H. McMahon, in a valuable account of the geology of Gilgit.

Two or three of these papers were distinctly mineralogical, and, after joining our Society in 1882, he contributed four papers to this Magazine. The first, in volume viii, discusses the cause of a polysynthetic structure in some porphyritic quartz crystals from India; the second, in vol. ix, describes the bowenite or pseudo-jade from Afghanistan, which he shows to be a true serpentine of somewhat unusual hardness, its probable origin being a rather exceptional peridotite; the third, in vol. x, discusses the micro-chemical analysis of rock-making minerals, giving the results of his own experiences; and the fourth, also in that volume, deals with the optical characters of the globules and spherulites of lithium phosphate and some other salts.

He was a frequent attendant at scientific gatherings and an effective contributor to discussions, obtaining a reputation as a terse, clear speaker, who never rose unless he had something valuable to say. He became F.G.S. in 1878, served more than once on its Council, and received its Lyell Medal in 1899, was President of the Geologists' Association in 1894–5, and of the Geological Section of the British Association at Belfast in 1902, and was elected a Fellow of the Royal Society in 1898.

Between two and three years ago his eyesight began to fail, which obliged him to resign, in June, 1902, the Treasurership of this Society, to which he had been elected in the previous November; his general health then began to decline, and after several months' illness he died on February 21, 1904. But while the body was weak, the mind remained vigorous, for his last scientific writing, published in the 'Geological Magazine' for November, 1903, shows all his wonted grasp of his subject, and power of polished satire. One who has discussed with him, in the field and in the study, questions more or less controversial, may be allowed to add that as a worker none could be more thorough, cautious, and conscientious, while as a man he wore 'the white flower of a blameless life,' and combined unswerving rectitude of character with a remarkable gentleness of disposition.

T. G. Bonney.

Clement Le Neve Foster (1841–1904).

By the death of Sir Clement Le Neve Foster, mineralogical science has lost an enthusiastic cultivator, one who by precept and example ever

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strove to promote the study of mineralogy, especially in its practical applications. He was the second son of the late Peter Le Neve Foster, for many years secretary of the Society of Arts, and was born at Camberwell on March 23, 1841. After early teaching at the Camberwell Collegiate School, he passed to a school at Boulogne, where at sixteen years of age he obtained his French degree of B.Sc., and then entered as a student at the Royal School of Mines. Here, in spite of youth, he succeeded, during his two years' career, in carrying off nearly all the prizes of the school, and when only nineteen years of age received an appointment on the Geological Survey. During his five years' work on the Survey, he accomplished, in conjunction with his colleague the late William Topley, a very brilliant piece of work, in the solution of the great problem of the denudation and drainage of the Weald.

In 1865, Le Neve Foster became lecturer to the Miners' Association of Cornwall and Devon, and in 1868 undertook exploring expeditions to Sinai and the Caratal gold-field in Venezuela; while from 1869 to 1872 he was resident engineer to some gold mines in Northern Italy.

Le Neve Foster again entered the Government service in 1872, being appointed H.M. Inspector of Mines in the district of Devon and Cornwall. He did much to introduce improved methods of working in the district, and by his efforts the lamentably high death-rate among the miners was greatly diminished; but in 1880 he was transferred to the North Wales district, of which he retained charge till his retirement in 1901.

It was during the period of Le Neve Foster's residence in Cornwall that this Society was founded, and he played an important part in its inauguration. Not only was he an original member and one of the first Council, but he became the first Foreign Secretary. The first volume of the 'Mineralogical Magazine' contains four papers from his pen—two on new minerals and mineral localities in Cornwall and Devon, and two dealing with methods of blowpipe analysis, a subject in which he always took the keenest interest and in which he was a recognized expert.

In later years, Le Neve Foster was so much occupied by his practical work in connexion with mining that he found little time for mineralogical research, though he retained a keen interest in the subject to the last.

At the time of his retirement from the Home Office, he had published twenty-nine annual official reports, which had an important influence in improving mining methods and ameliorating the conditions under which miners work. Until the time of his death he prepared for the Home Office a valuable yearly report on Mineral Statistics. He was also

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author of several treatises on mining, which have taken the highest position among scientific manuals.

In 1890, Le Neve Foster succeeded Sir Warington Smyth as Professor of Mining in the Royal College of Science and Royal School of Mines, where the work that he did in improving methods of teaching and in influencing the careers of the students was of the highest importance.

In 1897, while in his official capacity investigating the cause of a great disaster at the Snaefell Mine in the Isle of Man, he nearly lost his life from carbon-monoxide poisoning. Although his life was saved, his health was so seriously impaired that he resigned his position in the Home Office in 1901, but he still continued his work in the School of Mines with some interruptions. On April 19, after a short illness from which he rallied several times, he at last succumbed to the effects of the sad Snaefell accident, passing away at the age of 63.

Le Neve Foster was a D.Sc. of London, and was elected a Fellow of the Royal Society in 1892. Last year he received, in recognition of his great public services, the honour of knighthood.

J. W. J.

Frank Rutley (1842–1904).

Frank Rutley was born at Dover on May 14, 1842. He received his early education at the Faversham Grammar School, and then went for some years to a private English school at Bonn. At an early age he displayed the artistic tastes and skill in draughtsmanship which often proved of such great service to him in his subsequent scientific career.

That at an early date he had acquired a taste for geological study is shown by the first scientific communication from his pen. A curious subsidence took place at Lexden in Essex in the year 1861, which was described in the 'Geological Magazine' for 1865 by the Rev. Osmond Fisher. In a letter to the editor of the Magazine, Rutley reproduces a section made by him after a visit to the locality in 1862, and proceeds to criticize Mr. Fisher's theory for explaining the phenomenon. With characteristic modesty, Rutley writes that he questions Mr. Fisher's explanation 'with all humility, as I am but a very young hand at geology.'

It was in 1862 that Rutley entered the School of Mines, then at Jermyn Street, and he attended the lectures of Hofmann, Tyndall, Huxley, Ramsay, and Warington Smyth in the various branches of science taught there, though he did not complete the associateship course by devoting himself to technical work in mining or metallurgy.

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On leaving the School of Mines in 1864, Rutley joined the army and became an Ensign in the First Royal Scots regiment. But in 1867 he resigned his commission to take up an appointment as temporary Assistant Geologist upon the Geological Survey of England and Wales. The country he was sent to survey was a portion of the Lake District, where his old college companion Clifton Ward was already at work. In 1870 and 1871 Rutley wrote letters to the 'Geological Magazine' upon the subject of the glaciation of the Lake District, in which he displayed a minute knowledge of the geology of the area, in his criticism of the views of the late Mr. Mackintosh.

It was at this time that Rutley first showed his skill as a worker with the microscope, in the study of minerals and rocks—a branch of geological inquiry which had only recently been inaugurated by the labours of Sorby, David Forbes, Allport, and a few other workers in this country. This led to his being transferred to the central office of the Geological Survey at Jermyn Street, where he not only arranged a very instructive series of specimens for the Museum of Practical Geology, but also aided the surveyors in the field by his examination and description of rock-specimens sent up to town by them. To this period belong the important memoirs which he wrote for the Geological Survey upon 'The felsitic lavas of England and Wales' and 'The volcano of Brent Tor.'

As early as the year 1879, Rutley wrote a book, 'The Study of Rocks,' which was the first work of the kind in the English language, wherein an attempt was made to systematize the rapidly growing knowledge obtained by the microscopic study of rock-sections. In 1888, a more detailed text-book for students on 'Rock-forming Minerals' was the outcome of his experience as a teacher; while in 1895 he issued his 'Granites and Greenstones: a series of tables and notes for students of petrology.' Rutley also wrote a very compact and compendious manual of 'Mineralogy,' which passed through a number of editions.

In 1882, Rutley was appointed lecturer on mineralogy in the Geological Division of the Royal College of Science, with which the School of Mines had then been incorporated. He devoted himself with the most painstaking care to the instruction of the students, his patience and skill in illustration being always conspicuous. At the same time he was still carrying on work for the Geological Survey, and enriching geological literature by many valuable researches. In the 'Quarterly Journal of the Geological Society' twenty-six papers from his pen attest his constant activity. They include his valuable memoirs on the rocks of the Malvern Hills, upon the structures displayed by various glassy rocks, both fresh

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and devitrified, upon novaculites and quartzites, on the 'porfido rosso antico,' and on the dwindling of limestones. To the Royal Society he contributed two papers, one, in conjunction with Mr. Herman, 'On the microscopic characters of some specimens of devitrified glass, with notes on certain analogous structures in rocks'; the other, 'Notes on alteration induced by heat in certain vitreous rocks.' He also wrote papers for the 'Geological Magazine,' the Royal Microscopical Society, and the Geological Societies of Ireland and Cornwall.

Rutley joined the Geological Society in 1870, and in 1881 the balance of the proceeds of the Murchison Fund was awarded to him by the Council of the Society in recognition of his work and to assist him in his researches. He joined the Mineralogical Society in 1888, and served upon the Council from 1890–3, and in 1897–8. He wrote a paper on the classification and nomenclature of crystallites in the 'Mineralogical Magazine,' vol. ix, and several papers on quartz, zircon, manganite, and on fulgurites, &c., in vol. x of the Magazine. He was also a member of the French Mineralogical Society.

In 1898, Rutley's scientific activities and his work as a teacher were alike interrupted by a stroke of paralysis, and though he still continued to do a little work, his friends from that time missed his familiar presence at scientific gatherings. He passed away peacefully on May 16, 1904, after a long and patiently borne illness, and was buried in the Fulham Cemetery. Many friends mourn the loss of a true-hearted colleague and fellow-worker, and will long cherish a memory of the man and of the excellent work that he accomplished.

J. W. J.

Henry Palin Gurney (1847–1904).

Henry Palin Gurney, eldest son of Henry Gurney and Eleanor Palin, was born in London on September 7, 1847. He received his early education at the City of London School, proceeding afterwards to Clare College, Cambridge. There he distinguished himself both in Athletics and the Schools: he rowed in the college boat and ran for his University in the Oxford and Cambridge Sports of 1868 and 1869; he took both the Mathematical and Natural Sciences Triposes in the year 1870, being placed fourteenth wrangler in the former and in the first class in the latter; immediately afterwards he was elected to a college fellowship, which he held till 1883. In 1871 Mr. Gurney took orders in the Church of England, and for the next four years worked as curate to Canon Beck in one of the largest and poorest of London parishes, that of Rother-

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hithe; in the early part of that period he was married at Whitchurch in Herefordshire to Louisa, daughter of the Rev. H. Selby Hele, of Grays, Essex, and great-granddaughter of Bishop Horne.

Mr. Gurney's innate love of crystals had been developed under the influence of the Cambridge Professor, William Hallows Miller, during whose illness he later acted for some time as Deputy. Appreciating the difficulties which at that epoch presented themselves to English students, Mr. Gurney wrote a very simple and useful Manual of Crystallography (128 pages), founded on the Tract of Professor Miller and the Lectures of Professor Story-Maskelyne; it was published in 1875 by the Society for Promoting Christian Knowledge. He was one of the Original Members of the Crystallological Society founded on June 14, 1876, and was a Member of its first Council. At one time he meditated acceptance of an appointment in the Mineral Department of the British Museum, but, notwithstanding the great attractions which work in a mineral collection would have had for him, he did not feel justified, having regard to the interests of his family, in becoming a candidate for a post of which the prospective emoluments must be both uncertain and small.

Instead, therefore, of making research in mineralogy and crystallography his life-work, Mr. Gurney accepted an offer made to him and became a colleague, afterwards (1877–94) managing partner, of Mr. Walter Wren in the large establishment which the latter had instituted at Westbourne Park for the training of candidates for the various competitive examinations for posts in the Army and in the Home and Indian Civil Services; there his vast energy, physical and mental, found full employment. His remarkable powers of organization, and the personal influence he was able to bring to bear on young men of ability at a very critical period of their lives, contributed largely to the success of the undertaking. The pupils of that establishment now occupy prominent posts in every part of Greater Britain, and it thus comes about that few tutors have ever been more widely known and respected. During a large part (1876–88) of this period, he officiated as curate of the church of St. Peter in Bayswater.

When the Principalship of the Durham College of Science, Newcastle-upon-Tyne, fell vacant through the resignation of Dr. William Garnett, it was felt that the educational experience, the wide culture and attainments, and the personal character of Mr. Gurney marked him out as the ideal man for that important position. His appointment to the post has been abundantly justified during the ten years which have since elapsed.

voted himself to the advancement of the interests of the college

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in every possible way. Of the thousands of students who have passed through the institution during his tenure of office, many will long remember his kindly advice and ready help. His charm of manner and sweetness of disposition made him everywhere popular; and at distributions of school-prizes and public meetings in general in Newcastle and the surrounding district, he was sure of a hearty welcome. He took a leading part in inducing the promoters of the Armstrong Memorial Fund to devote its proceeds to the completion of the college buildings, and he afterwards gave help in the encouragement of subscriptions. Mr. Gurney provided a remarkable illustration of the well-known fact that the busiest man is the one who is most ready to add to his work and responsibilities: he was the representative of the college on the governing bodies of schools at Newcastle, Rothbury, Hartlepool, and Middlesbrough; he was a co-opted member of both the Newcastle and Northumberland Education Committees; he was Chaplain to the Bishop of Newcastle, and also to the Third Volunteer Battalion of the Northumberland Fusiliers; he was Warden of the Newcastle Diocesan House of Mercy.

Notwithstanding the great multiplicity of the duties which fell to him as Principal, and the demands made on his time by the professorship of mathematics which he later combined therewith, Mr. Gurney found it possible to give some attention to the development of his old subject, the study of crystals. Impressed with the importance of crystallography both as an independent science and as auxiliary to chemistry, physics, mineralogy, and petrology, he equipped the college with apparatus for the measurement of the angles and for the determination of the symmetry and optical characters of crystals, and arranged that opportunity for the acquisition of a theoretical and practical knowledge of the science should be provided for Newcastle students.

Mr. Gurney received the honorary degree of D.C.L. from the University of Durham; he was a Fellow of the Geological and Physical Societies, and for several years was a Member of the Council of the Mineralogical Society.

Whenever it was practicable for him, Mr. Gurney sought complete relaxation and change of thought in travel, spending many of his vacations abroad and availing himself of every opportunity of visiting places of general or geological interest both in Europe and America. With the present writer he spent several happy holidays; on one occasion journeying to Moscow, Nijni Novgorod, and down the Volga to Kazan, afterwards making an excursion with other members of the International

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Geological Congress to various noteworthy places in Finland: a brief account of the latter he gave in his 'Notes on the Geology of Finland.' He was an ideal companion; full of energy and enthusiasm; of infinite patience, good temper, and cheerfulness; indeed, to see his pleasant face and hear his hearty laugh was almost a holiday in itself. Only a few short weeks ago he proposed that they should again spend a few weeks together, this time at Arolla in Switzerland, where he was to go with two of his daughters, but the writer was unable to leave London. Soon afterwards came the startling news of his death. With only a walking-stick in his hand, he had started off alone at 8 a.m. on August 13, not saying, probably not knowing, how far he was likely to go. Night came and he did not return. Search was immediately begun, and by dusk the next day his footmarks had been discovered on an *arête* of the Gysa, a southern spur of Mount Roussette; there they ceased. Soon after dawn on the following morning his body was discovered several hundred feet below; his watch had stopped at nearly twelve. Notwithstanding the caution and carefulness which were ever prominent features in his own character, and were strongly impressed by him on others, he had doubtless been gradually led on by the beauty of the view to climb higher and higher, and had eventually and unexpectedly found himself in a place where a slip was easy and would mean instant death.

His loss will long be felt far and wide, more especially in the North of England, where he had lived for the last ten years; but for the members of his family and his intimate friends, more especially for one to whom he always showed the kind feeling of a brother, it will cast a shadow over what remains of life. L. FLETCHER.

FERDINAND ANDRÉ FOUQUÉ (1828–1904).

By the death of Professor Fouqué, on March 7, our Society loses a distinguished Honorary Member, elected in 1898. Since 1877 he had been Professor of Natural History in the Collège de France, and in 1881 was elected Membre de l'Institut. His first paper, with St. Claire Deville in 1854, dealt with the losses experienced by minerals when heated, and his studies in volcanic geology led to the publication, in 1879, of his great work 'Santorin et ses éruptions.' In conjunction with Michel Lévy he published two other important monographs—'Minéralogie micrographique: roches éruptives françaises' (1879), and 'Synthèse des minéraux et des roches' (1882)—and he was the author, often also in collaboration with Michel Lévy, of numerous papers on petrology and on rock-forming minerals.

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Edward John Chapman (1821–1904).

Born in London on February 22, 1821, Dr. Chapman was educated in France and Germany, and after acting as Professor of Mineralogy in University College, London, was for many years (1853–1895) Professor of Mineralogy and Geology in University College, Toronto. He died at Hampton Wick, near London, on January 28, 1904. In 1843, he published a 'Practical mineralogy,' and a posthumous work bears the title 'Mineral systems, a review: with outline of an attempted classification of minerals in natural groups.' He was also the author of several other separately-published works, including a volume of poems. Many of his earlier mineralogical papers, on blowpipe analysis, classification of minerals, &c., appeared in the 'Philosophical Magazine,' while later papers, on the mineralogy and geology of Canada, appeared in Canadian journals.

Charles Soret (1854–1904).

Charles Soret, formerly Professor of Mineralogy and afterwards of Physics, and also for a time Rector of the University of Geneva, died at Geneva on April 4. He was the son of Jacques Louis Soret, also Professor of Physics at Geneva. His published papers treat of the optical and thermal properties of crystals, and he was the author of 'Éléments de cristallographie physique' (1893).

Sándor Schmidt (1855–1904).

From 1876 until 1895 Alexander Schmidt was an assistant in the mineralogical division of the Hungarian National Museum, during which time he obtained special permission to study for two years (1882–3) at Strassburg under Professor Groth. Previous to his appointment in 1895 as Ordinary Professor of Mineralogy and Geology in the Polytechnic at Budapest, he was Extraordinary Professor of Mineralogy in the University. His several papers are mainly descriptive of Hungarian minerals. He was born at Szegedin, Comitat Csongrád, Hungary, in 1855, and died at Budapest on May 16, 1904.

Édouard Cumenge (1828–1902).

Cumenge's career as a mining expert commenced with his appointment in the French Corps des Mines, but after 1852 his position was only honorary (Ingénieur en chef honoraire des Mines). With C. Friedel and Mallard he described guejarite, boleite, and carnotite as new species, and the mineral cumengeite was named after him.

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NOTES.

Testimonial to Professor Groth.—Two years ago, when the 'Zeitschrift für Krystallographie und Mineralogie,' founded in 1877 by Professor Paul Groth, completed the twenty-fifth year of publication, various mineralogists in different countries felt that such an epoch provided a fitting opportunity for commemorating the invaluable services which Professor Groth has rendered to mineralogy and crystallography by his initiation and continuous editorship of that journal, which now extends to thirty-nine volumes. Accordingly, Professor M. H. N. Story-Maskelyne, Professor W. J. Lewis, Mr. L. Fletcher, and Professor H. A. Miers, formed themselves into a Committee, and charged themselves with the pleasant task of bringing the well-wishers of Professor Groth in different parts of the world into touch with each other. The letter, sent out by the secretaries on December 6, 1902, met with a hearty response, and a sufficient sum of money was obtained to enable the Committee to commission Professor Eduard Grützner, of Munich, to paint a portrait of Professor Groth. The picture, together with the following letter from Professor M. H. N. Story-Maskelyne, the Chairman of the London Committee, was formally presented to Professor Groth at Munich on April 30, 1904.

An excellent photogravure (measuring $12 \times 15\frac{1}{2}$ inches) of the portrait, reproduced by Dr. E. Albert & Co., of Munich, has been sent to each of the 273 individual subscribers to the fund.

The Athenaeum, Pall Mall, London, S.W.
April 28, 1904.

My dear Colleague,

The correspondence which has passed between our friend Mr. Fletcher, of the British Museum, and yourself, and has resulted in the successful completion of your portrait by the distinguished artist Professor Grützner, will find its appropriate sequel in this letter.

It is accordingly my most welcome duty, as representing the London Committee that initiated our proceedings, to ask your acceptance of the portrait, which I hereby present to you in the name of many friends in many lands: some personally known to you, others without that privilege, but all wishing to manifest to you their grateful acknowledgement of the services rendered to Science by your enlightened initiation and laborious editorship through a quarter of a century of the 'Zeitschrift für Krystallographie und Mineralogie,' a continuous record of nearly everything that has been done in those sciences since the year 1877, and an emporium of theory and of fact absolutely necessary for all who would pursue successful study and research in them.

While conveying to you this expression of our profound appreciation, which

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I do on behalf of the numerous contributors named in the accompanying list, I have an especial pleasure in being able to subscribe myself,

My dear friend and colleague,
as most truly yours,
NEVIL STORY-MASKELYNE.

Professor Paul Groth, Munich.

In acknowledgement of the above letter, Professor Groth wrote as follows:—

München, den 30. April 1904.

Herrn Professor M. H. N. Story-Maskelyne.

HOCHVEREHRTER HERR KOLLEGE!

Mit dem aufrichtigsten Danke für Ihr so überaus liebenswürdiges Schreiben zeige ich Ihnen an, dass das schöne und wertvolle Gemälde, welches Herr Professor E. Grützner auf Wunsch des aus Ihnen, dem allverehrten Nestor unserer Wissenschaft, und unseren Freunden W. J. Lewis, L. Fletcher und H. A. Miers bestehenden Comités ausgeführt hat, mir nunmehr durch die freundliche Vermittelung des Herrn Professor K. Oebbeke, als hiesigen Vertreter des Comités, übergeben worden ist.

Als Herr Kollege L. Fletcher mir die erste Mitteilung von der mir zugedachten Ehrung machte, waren die Vorbereitungen dazu schon so weit gediehen, dass ich sie akzeptieren musste, obgleich ich mir recht wohl bewusst war, wie weit dieselbe über mein Verdienst hinausgehe. Aus der mir von Ihnen gütigst übersandten Liste der Teilnehmer ersehe ich nun, dass nicht nur die Träger so vieler mir lieber und wohlbekannter Namen von Freunden und Schülern, sondern auch zahlreiche, mir persönlich nicht bekannte Fachgenossen in England und in fast allen andern ausserdeutschen Kulturländern zu dieser Ehrung beigetragen haben. In erster Linie ist dies das Verdienst der Korrespondenten des Comités für die verschiedenen Länder, der Herren H. Bäckström für Schweden, H. Baumhauer für die Schweiz, F. Becke für Österreich, W. C. Brögger für Norwegen, S. Calderón für Spanien, G. Cesàro für Belgien, F. W. Clarke für die Vereinigten Staaten, B. J. Harrington für Canada, F. J. Loewinson-Lessing und P. Zemjatschensky für Russland, R. Panebianco für Italien, N. V. Ussing für Dänemark, G. Wyrouboff für Frankreich.

Wenn es für mich auch fast beschämend ist, dass so viele ausgezeichnete Forscher es nicht verschmäht haben, für diesen Zweck Zeit und Mühe zu opfern, so ist es mir doch andererseits eine grosse Freude und Genugtuung, hieraus zu ersehen, dass die bescheidenen Dienste, welche ich der Wissenschaft durch die Gründung und Leitung der 'Zeitschrift' geleistet habe, eine so allgemeine und freudige Anerkennung gefunden haben.

Lassen Sie mich deshalb Ihnen, den Herren Comité-Mitgliedern und Korrespondenten und sämtlichen Teilnehmern meinen allerherzlichsten Dank aussprechen für die Ehrung, welche sie mir durch die Darbringung eines Geschenkes erwiesen haben, dessen Anblick mir bis zu meinem Lebensende die Erinnerung an die mir dadurch bezeugte freundliche Gesinnung aller Teilnehmer wacherhalten wird.

Indem ich diesem Dank noch die Versicherung meiner ausgezeichneten Hochachtung für Sie hinzufüge, verbleibe ich

Ihr treu und dankbar ergebener
P. GROTH.

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To the memory of Professor Antonio D'Achiardi (1839–1902) there has been issued a volume representing the work done, during the year 1903, in the Mineralogical Laboratory of the University of Pisa. The volume (Pisa, 1903, 173 pp. and 6 plates) consists of a collection of eleven mineralogical and petrographical papers, by Professor Giovanni D'Achiardi (his father's successor at Pisa), Dr. Ernesto Manasse, and Dr. Piero Aloisi, which have already appeared in the 'Atti della Società Toscana di Scienze Naturali.' Earlier in the same year there was also published a report of the commemoration service, together with a portrait, biographical notice, and list of papers of the late professor.

An instance of the inconsistencies which may readily arise in the statement of mineral localities is noted by Professor V. Goldschmidt (Zeits. Kryst. Min., 1903, vol. xxxviii, p. 498). The locality of certain highly modified crystals of pyrites from Hungary has been variously stated as: (1) Porkura in the Csetrás mountains, (2) Csetrás, (3) Kis-Almás. These all refer to the same spot, which is situated in the valley of the Szlatyin brook near to the villages of Porkura and Kis-Almás (but within the boundaries of the latter) in Comitat Hunyad, Transylvania.

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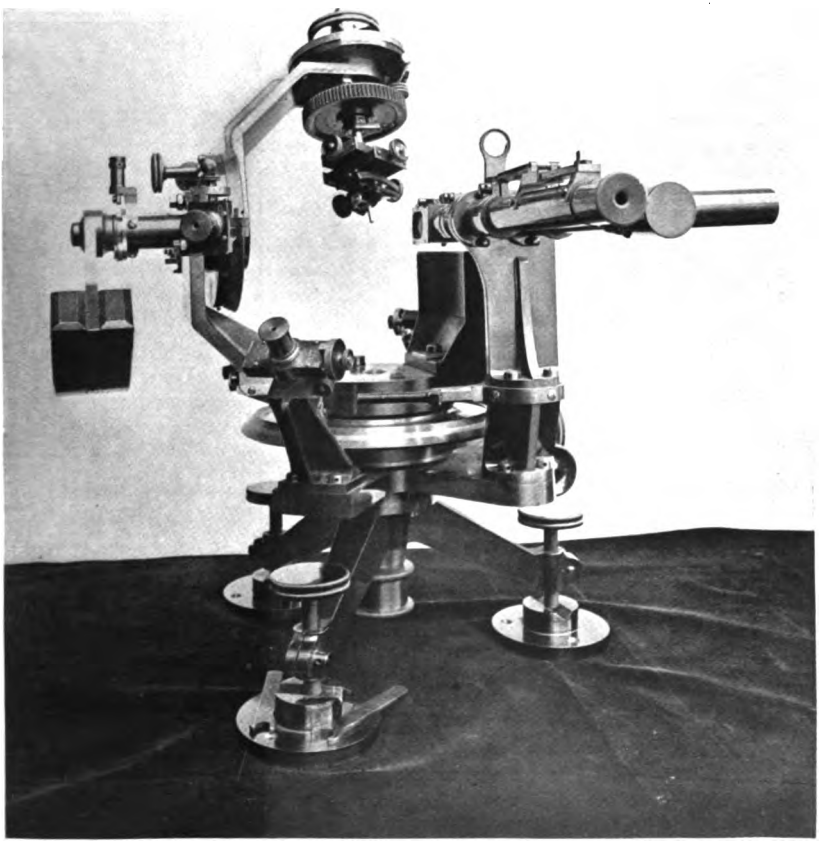

G. F. HERBERT SMITH: THREE-CIRCLE GONIOMETER.

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Plate III.

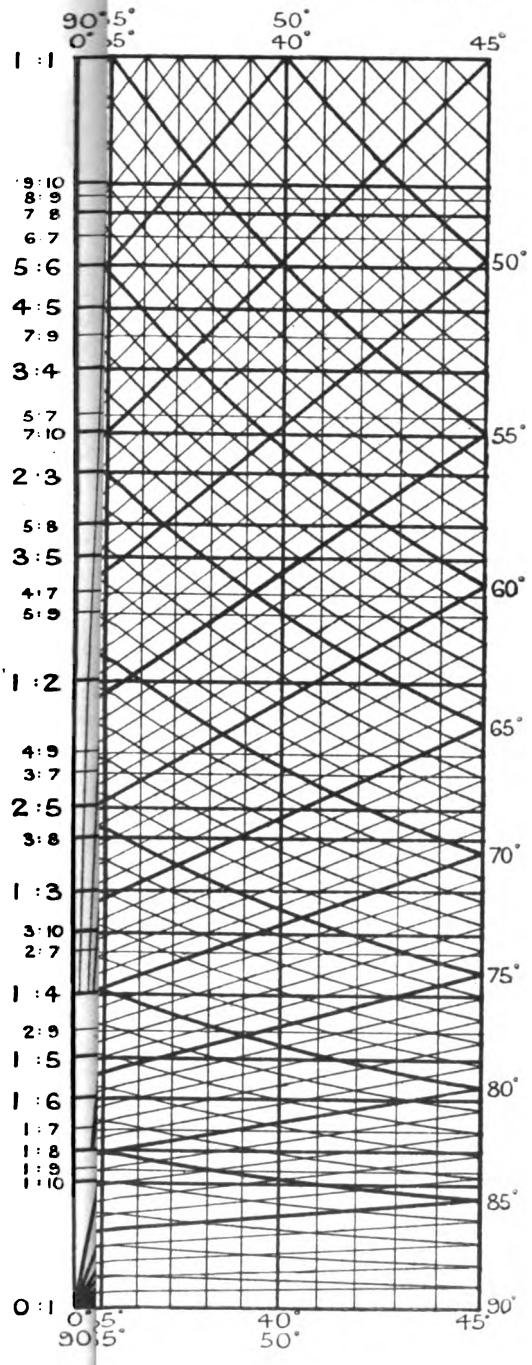

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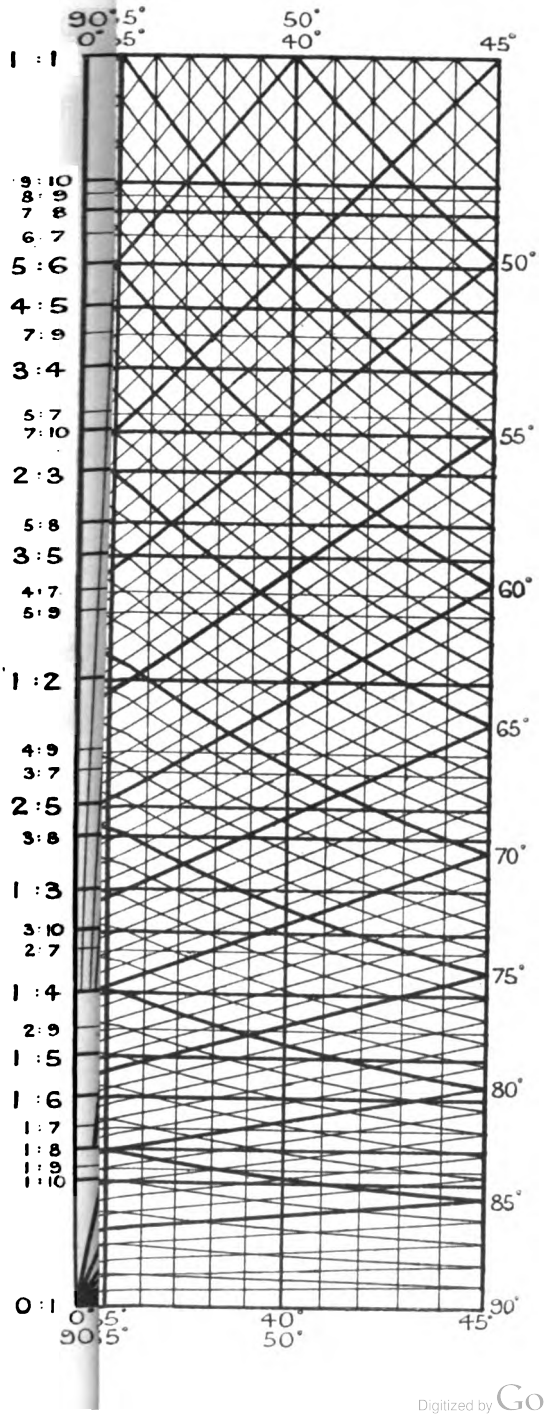
Plate III.



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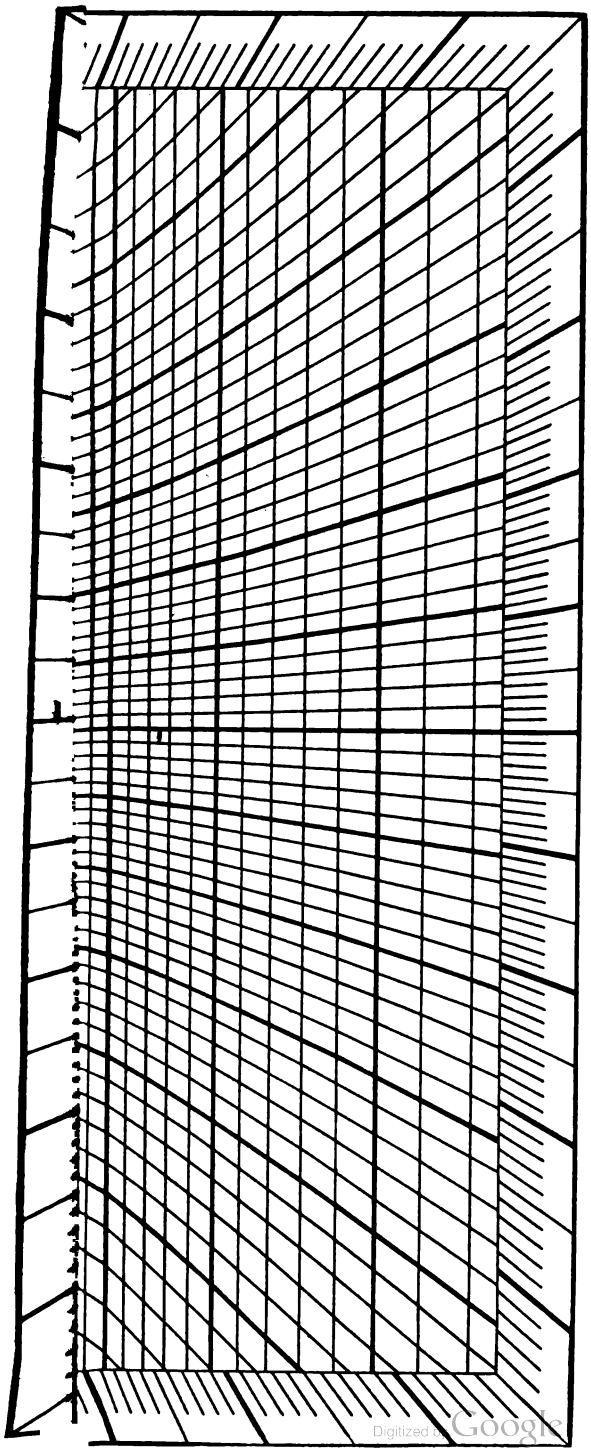

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THE MINERALOGICAL MAGAZINE

AND

JOURNAL OF

THE MINERALOGICAL SOCIETY.

No. 64. May, 1905. Vol. XIV.

A new device for separating minerals by means of heavy liquids.

By HAROLD HARTLEY, M.A.
Fellow of Balliol College, Oxford.

[Read January 22, 1901.]

DURING the investigation of a zeolite it became necessary to separate small quantities of zeolitic material from a mixture of calcite and other heavier minerals; this could be done most easily by using a liquid of such density that the zeolite just floated, while all the other minerals sank to the bottom. A solution of potassium-mercuric iodide could not be used, as this reacts chemically with zeolites and alters their composition; acetylene tetrabromide diluted with benzene was therefore chosen, and in consequence the apparatus had to be made entirely of glass. Certain difficulties were found in using the ordinary form of glass separating apparatus, and to overcome these the form here described was devised.

The accompanying figure shows the apparatus in section and about one-third its actual size; it consists of a glass tube A, about 22 cm. long, and 2·5 cm. wide, slightly constricted in the middle, and closed by a wide-bore Geissler-tap C at its lower end. The powdered mixture of minerals is introduced into A with an organic liquid of suitable density for separating its lightest or heaviest constituent. The tube is closed by a cork or glass stopper to prevent evaporation and consequent change of density in the liquid. It is gently shaken by short, rapid movements, up and down and from side to side, so as to allow the lighter particles to rise,

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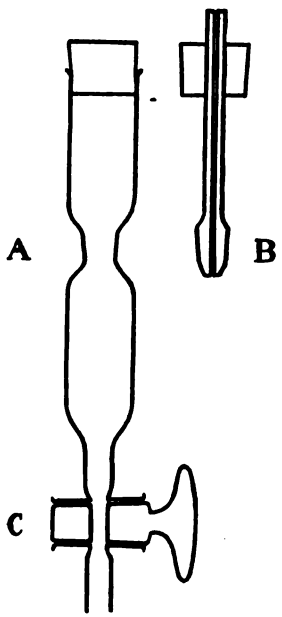
and by continuing this long enough it is possible to prevent the entanglement of either light or heavy particles in the wrong part of the liquid. It is also advisable to incline the tube at an angle of 45°, rotating it and tapping it at the same time, to make sure that no particles are adhering to the glass near the constriction.

When the separation seems to be complete, the cork is taken out and replaced by another carrying the capillary-tube B, which is thickened at its lower end and ground so as to fit the constriction in A. When B has been pushed home, the lower tap is opened and the liquid flows out, carrying with it the heavier portions of the powder; these can be filtered off, and the heavy liquid is ready for use again.



Separator.

Some particles always remain attached to the inside of A; these are washed out with the liquid that is being used as a diluent (in this case benzene) by sucking up a little through C by means of a rubber-tube attached to the end of the capillary-tube B, then closing the tap C, swilling out the tube, and letting the liquid run out of the tap again. By repeating this operation the lower chamber can be freed from any trace of solid; and by closing the tap C and removing the capillary-tube the liquid flows down from the upper chamber, and if required can be allowed to flow out and can be filtered like that from the lower, the adhering particles being washed out with the same lighter liquid.

The apparatus has mainly been used in cases where it was required to separate a very small percentage of the lightest constituent from a large quantity of material, and it was found convenient not to remove the lightest portion from the apparatus at the end of each separation, but when the heavier part has been removed, the liquid is poured in again, another portion of material added, and the process repeated. In this way the lightest portion is concentrated and no loss is incurred by successive separations; and the method gives very satisfactory results both as regards yield and purity.

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The following were found to be the chief advantages over the ordinary forms of 'all glass' apparatus.

In other 'all glass' separators, after the powdered mixture has been separated by the heavy liquid, the latter is allowed to flow out at the bottom of the tube in which the separation has taken place, and, when only the lightest solid remains, the flow is interrupted by turning a tap or inserting a ground-glass plug. In both cases some solid is apt to get into the joint and spoil the experiment and not infrequently break the apparatus. This possibility is prevented in the apparatus described, as the tube B is inserted while the liquid is at rest and it is easy to see that there are no particles in the joint. Another advantage is the possibility of using it as a concentrator in the way mentioned.

The apparatus can be obtained from Messrs. Müller, Orme & Co., 148 High Holborn, London.

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Some new minerals from the Binnenthal, Switzerland.

By R. H. Solly, M.A.

[Read November 17, 1908, and November 15, 1904.]

Hutchinsonite.

A PRELIMINARY notice of this new mineral, named in honour of Dr. Arthur Hutchinson, Demonstrator of Mineralogy in the University of Cambridge, was read before the Cambridge Philosophical Society in October, 1908 [1]. The material was first found, in the white crystalline dolomite of the Lengenbach quarry, during my visit to the Binnenthal in the summer of 1908. More material was received in November of the same year, and a further supply was obtained in 1904 [2].

The characters of hutchinsonite, so far as yet determined, are the following:—

System: orthorhombic. $a : b : c = 0{\cdot}8175 : 1 : 0{\cdot}7549$.

$(100) : (110) = 39° 16'$; $(010) : (011) = 52° 57'$; $(001) : (101) = 42° 43'$.

These elements are calculated from the measured angles

$$(100) : (840) = 47° 28' \text{ and } (100) : (101) = 47° 17'.$$

The usual habit is a flattened rhombic prism [100,010], with numerous small dome- and pyramid-faces. The plane (180) is very common and often very largely developed.

The colour is red to greyish-black, the red being sometimes lighter and sometimes darker in shade. The streak is vermilion. The crystals are transparent to nearly opaque. Hardness, 1½ to 2. Cleavage, parallel to (100), good.

Hutchinsonite usually occurs as very small crystals in the white dolomite, or is closely associated with sartorite and rathite. In the latter case two modes of occurrence may be distinguished: (1) as small, dark red prisms symmetrically arranged on the prism-planes of the sartorite or rathite; (2) as small, stout, light red crystals coating the terminal planes of these minerals.

In the preliminary account, quoted above, it was stated that the new

[1] Proc. Cambridge Phil. Soc., 1904, vol. xii, p. 277. The new mineral is there briefly described, but without name.

[2] Leaving England in December, 1908 for an indefinite period, I handed over the whole of this material, together with the other red minerals—smithite and trechmannite—to the British Museum for the investigation to be completed. A fuller account, by Mr. G. T. Prior and Mr. G. F. Herbert Smith, of these new minerals will appear in a subsequent number of this magazine.

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mineral contains arsenic, sulphur, and probably lead; but owing to its very intimate association with sartorite and rathite, and in the absence of any confirmatory tests, this must be considered to be doubtful [1].

The following is a list of the best developed faces; I have also observed a number of other smaller ill-defined planes:—

{100}, {010}, {001}, {850}, {870}, {110}, {780}, {840}, {580}, {120}, {880}, {140}, {180}, {502}, {201}, {802}, {101}, {804}, {102}, {104}, {011}, {822}, {111}, {844}, {122}, {144}.

A selection of the angles measured on hutchinsonite is given below:—

	Calculated.	Measured.	
Zone [100,010].			
(100) : (850) =	27° 8½′	26°56′	
: (870) =	35 34½	35 51	35°49′
: (110) =	39 16	39 20	
: (780) =	43 3	43 4	43 2
: (840) =	47 28	47 25	47 28
: (580) =	52 36	52 39	52 30
: (120) =	58 33	58 36	58 32
: (880) =	65 21½	65 29	65 21
: (140) =	73 0	72 55	73 3
: (180) =	81 21	81 19	81 21
: (010) =	90 0	90 0	
Zone [100,001].			
(100) : (502) =	23 25½	23 35	
: (201) =	28 26	28 24	28 28
: (802) =	35 50	35 45	
: (101) =	47 17	47 17	47 19
: (804) =	55 17	55 32	
: (102) =	65 13	65 15	
: (104) =	77 0	77 1	
: (001) =	90 0	90 0	
Zone [100,011].			
(100) : (822) =	42 7	42 10	
: (111) =	53 36½	53 36	53 37
: (844) =	61 3½	61 4	61 6
: (122) =	69 46	69 50	
: (144) =	79 33½	79 30	

[1] Quite recently, Mr. G. T. Prior has found hutchinsonite to be a sulpharsenite of thallium, lead, silver, and copper: the presence of nearly 20 per cent. of thallium is of especial interest ('Nature,' April 6, 1905, vol. lxxi, p. 584).

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Smithite.

System: monoclinic. $a:b:c = 2{\cdot}2309:1:1{\cdot}9657$; $\beta = 78°\,47\frac{1}{2}'$. (100):(101) = 42° 22′; (101):(001) = 36° 25½′; (010):(111) = 87° 8′. These elements are calculated from the angles (100):(101) = 42° 22′, (100):(10$\bar{1}$) = 55° 0′, and (100):(111) = 68° 24′, measured on the best and largest crystal.

The usual habit resembles a flattened hexagonal pyramid with basal plane, the plane (100) being largely developed and combined with the three zones [100,001], [100,111], [100,11$\bar{1}$] equally developed

The colour is light red. Lustre, adamantine. Streak, vermilion. The crystals are transparent to translucent. Hardness, 1½–2. Cleavage, parallel to (100), highly perfect. The surface of the crystals becomes altered on exposure to light, changing from a pure red to an orange-red colour.

Smithite is associated with hutchinsonite, sartorite, and rathite in the white dolomite of the Lengenbach.

Sixteen forms were observed, viz.:—

{100}, {001}, {101}, {10$\bar{1}$}, {411}, {311}, {211}, {322}, {111}, {355}, {011}, {51$\bar{1}$}, {41$\bar{1}$}, {21$\bar{1}$}, {11$\bar{1}$}, {21$\bar{2}$}.

	Calculated.	Measured.	
Zone [100,101].			
(100):(101) =	42°22′	42°22′	42°24′
:(001) =	78 47½	78 47	78 45
:(10$\bar{1}$) =	125 0	125 0	125 0
Zone [100,011].			
(100):(411) =	30 0	30 5	30 0
:(311) =	37 7	37 7	37 9
:(211) =	47 43	47 45	47 42
:(322) =	54 50	54 49	
:(111) =	68 24	68 24	
:(355) =	71 25	71 23	
:(011) =	84 50	85 0	
(1$\bar{0}$0):(51$\bar{1}$) =	27 1½	27 4	
:(4$\bar{1}$1) =	32 49½	32 11	
:(2$\bar{1}$1) =	53 52½	53 53	
:(1$\bar{1}$1) =	72 16	72 11	
:(2$\bar{1}$2) =	83 27½	83 48	
:(011) =	95 10	94 57	

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I have named this mineral after Mr. G. F. Herbert Smith, M.A., Assistant in the Mineral Department of the British Museum [1].

Trechmannite.

After the discovery of the two red minerals described above, I received from Dr. C. O. Trechmann a specimen with a few minute red crystals resting on a crystal of baumhauerite in a cavity in the white dolomite. It was necessary to remove the crystals from the matrix for examination, and it was found that in symmetry they differed from both hutchinsonite and smithite. I therefore distinguish this third red mineral by the name trechmannite, after Dr. Charles O. Trechmann, who for many years has worked at the minerals of the Binnenthal. Dr. Trechmann's specimen was taken from the Lengenbach quarry in the summer of 1902; a second specimen, with a single crystal of trechmannite resting on a crystal of tennantite was found in 1904.

The following characters have been determined:—

System: rhombohedral. $(111):(100) = 87° 7\frac{1}{2}'$. $a:c = 1:0{\cdot}6556$.

The element was calculated from $(1\bar{1}0):(100) = 58° 29'$ observed on two crystals.

The two crystals which were measured consist of portions of hexagonal prisms with some small pyramidal and rhombohedral faces. One crystal exhibits a cleavage perpendicular to the prism.

In colour, streak, and hardness it resembles hutchinsonite and smithite.

The following is a list of forms observed:—

$o\{111\}$, $r\{100\}$, $x\{212\}$, $z\{313\}$, $a\{1\bar{1}0\}$, $b\{2\bar{1}\bar{1}\}$, $d\{527\}$, $f_{\cdot}825\}$.

There are also a number of narrow planes lying in the zone [10$\bar{1}$,010].

	Calculated.	Measured.
$(10\bar{1}):(527)$	16° 6′	16°17′
$(10\bar{1}):(825)$	23 25	23 23
$(10\bar{1}):(11\bar{2})$	30 0	29 57
$(10\bar{1}):(01\bar{1})$	60 0	60 0
$(10\bar{1}):(313)$	17 41	17 43
$(10\bar{1}):(21\bar{3})$	25 33½	25 34
$(10\bar{1}):(010)$	90 0	89 55
$(101):(\bar{2}12)$	25 33½	25 30

	Calculated.	Measured.
$(10\bar{1}):(100)$	58°29′	58°29′
$(100):(001)$	63 2	63 1
$(01\bar{1}):(21\bar{2})$	47 25	47 25
$(1\bar{1}0):(21\bar{2})$	76 57	77 1
$(21\bar{2}):(11\bar{2})$	26 6	26 12
$(10\bar{1}):(111)$	90 0	90 0
$(\bar{1}10):(111)$	90 0	90 0

[1] Since the above was written an analysis of smithite has been made by Mr. G. T. Prior, the results of which lead to the formula $AgAsS_2$.

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Marrite.

The crystals of this new mineral are highly modified and are usually doubly terminated. They are tarnished with red, yellow, and blue colours, and on this account might, at first sight, be mistaken for tennantite ('binnite') or iron-pyrites. The only specimen, which up to the present time has been found, was taken from the Lengenbach quarry in July, 1904. On the matrix of white crystalline dolomite there are about fifteen small crystals, averaging 2–3 mm. across, of marrite deposited on or about tarnished crystals of lengenbachite (p. 78) and iron-pyrites. Three crystals were removed from the matrix; two being measured with the results given below, and the third, after goniometric verification, being used for determining the streak and hardness of the mineral. The specific gravity and chemical composition of the crystals could not be determined without sacrificing the unique specimen.

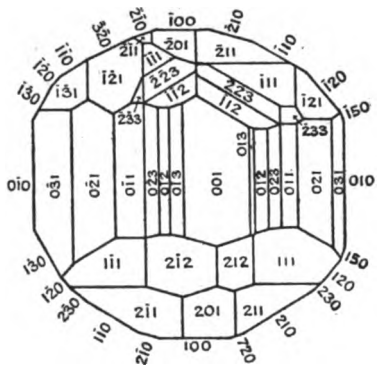

Fig. 1.—Orthographic projection of marrite.

The system of crystallization is monoclinic, with the elements:—

$$a : b : c = 0{\cdot}57634 : 1 : 0{\cdot}47389;$$
$$\beta = 88° 45',$$

as calculated from the measured angles (100) : (001) = 88° 45', (010) : (110) = 60° 8', and (010) : (011) = 64° 39'. The common habit of the crystals resembles a cube modified by {*hk*0} and {*hkl*} planes (fig. 1). The crystals are aggregated together in such a manner as to suggest the presence of twinning about the plane (001).

The colour of marrite is lead-grey to steel-grey, but the crystals are usually tarnished with iridescent colours. The lustre is metallic and brilliant. The streak is black with a slight tinge of chocolate-colour. The mineral is opaque. No cleavage was observed; the fracture is conchoidal. Hardness, 3.

The name marrite is proposed in honour of Dr. John Edward Marr, F.R.S., of Cambridge.

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List of (Forty) Forms observed on Marrite.

Symbol.	Indices.	Size of face.	Character of reflection.	Symbol.	Indices.	Size of face.	Character of reflection.
a	{100}	Large	Sharp	$\frac{1}{3}k$	{073}	Narrow	Fair
b	{010}	,,	,,	$2k$	{021}	Large	Good
c	{001}	,,	,,	k	{011}	Fair	Good
$-2h$	{201}	Fair size	Fair	$\frac{2}{3}k$	{023}	Narrow	Fair
$-h$	{101}	Very small	Poor	$\frac{1}{2}k$	{012}	Large	Sharp
$+2h$	{20$\bar{1}$}	Fair size	Sharp	$\frac{1}{3}k$	{013}	Narrow	Fair
$+h$	{10$\bar{1}$}	Very small	Poor	$\frac{1}{5}k$	{015}	,,	,,
$7r$	{170}	Narrow	Broad	$-2q$	{121}	Very small	Faint
$6r$	{160}	,,	,,	$-p$	{111}	Fair	Good
$5r$	{150}	,,	Fair	$-2t$	{212}	Small	Fair
$4r$	{140}	Fair size	Good	$-2u$	{211}	,,	,,
$3r$	{130}	Narrow	Fair	$+3v$	{13$\bar{1}$}	,,	,,
$2r$	{120}	Large	Sharp	$+2q$	{12$\bar{1}$}	,,	,,
$\frac{3}{2}r$	{230}	Fair size	Fair	$+p$	{11$\bar{1}$}	Fair	Good
r	{110}	Large	Sharp	$+2p$	{11$\bar{2}$}	Small	Fair
$\frac{3}{4}s$	{320}	Narrow	Fair	$+2t$	{21$\bar{2}$}	Fair	Good
$2s$	{210}	,,	,,	$+2u$	{21$\bar{1}$}	,,	,,
$\frac{1}{3}s$	{720}	,,	,,	$+s$	{283}	Small	Fair
$\frac{1}{3}k$	{072}	,,	Good	$+x$	{223}	,,	,,
$3k$	{031}	Large	Sharp	$+y$	{23$\bar{1}$}	,,	,,

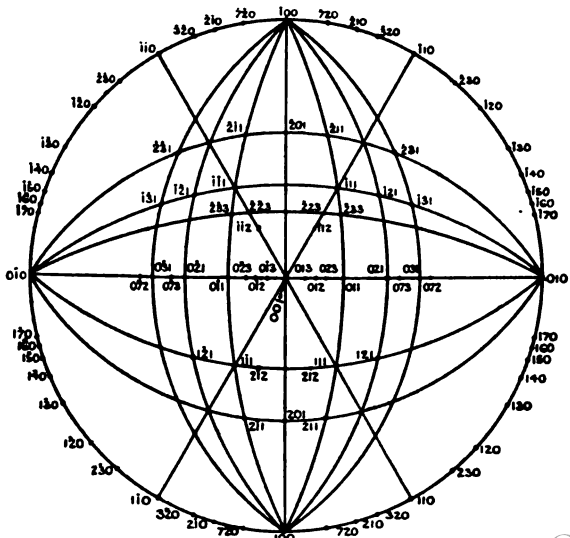

Fig. 2.—Stereographic projection of marrite.

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Calculated and Measured Angles of Marrite.

	Calculated.	Measured. I.	Measured. II.		Calculated.	Measured. I.	Measured. II.
Zone [100,001].	° ′	° ′	° ′	Zone [010,203].	° ′	° ′	° ′
(100) : (201)	30 58	30 56	30 59	(010) : (233)	67 42	67 24	67 30
: (101)	49 50	—	—	: (223)	74 19	74 19	—
: (001)	88 45	88 45	88 45	Zone [010,101].			
(100) : (20$\bar{1}$)	31 38	31 38	31 38	(010) : (13$\bar{1}$)	42 1	42 0	—
: (10$\bar{1}$)	51 19	—	—	: (12$\bar{1}$)	53 30	53 33	53 31
: (00$\bar{1}$)	91 15	91 15	91 15	: (11$\bar{1}$)	69 42	69 44	69 43
Zone [010,001].				: (212)	79 31	79 40	79 35
(010) : (072)	31 5½	31 7	31 8	Zone [010,201]			
: (031)	35 8	35 8	35 8	(010) : (23$\bar{1}$)	53 21	53 23	—
: (073)	42 8	42 15	—	: (21$\bar{1}$)	76 3	76 4	76 10
: (021)	46 32½	46 32	46 32	: (20$\bar{1}$)	90 0	90 0	90 0
: (011)	64 39	64 40	64 39	Zone [100,011].			
: (023)	72 28½	72 29	—	(100) : (211)	33 27	33 33	33 32
: (012)	76 40½	76 39	76 40	: (111)	52 42	52 37	52 38
: (013)	81 1½	81 5	—	: (011)	88 53	88 45	88 53
: (015)	84 35	—	84 30	(100) : (21$\bar{1}$)	34 17½	34 17	34 14
: (001)	90 0	90 0	90 0	: (11$\bar{1}$)	54 7	54 5	54 3
Zone [010,100].				: (01$\bar{1}$)	91 7	91 15	91 4
(010) : (170)	13 55½	14 0	—	Zone [001,110].			
: (160)	16 8	16 5	—	(001) : (111)	42 59½	43 2	43 2
: (150)	19 8½	19 6	19 0	: (110)	88 54½	88 58	88 58
: (140)	23 27	23 28	23 30	(001) : ($\bar{1}$12)	25 35	—	25 47
: (130)	30 3	30 1	—	: (223)	32 38	32 48	32 38
: (120)	40 57	40 57	41 0	: ($\bar{1}$11)	44 1	44 2	44 1
: (230)	49 6	49 6	49 0	: ($\bar{1}$10)	91 5½	91 3	91 4
: (110)	60 3	60 3	60 3	Zone [001,120].			
: (320)	68 59	69 0	69 1	(001) : (121)	50 56	50 54	—
: (210)	73 55½	73 56	73 58	: (120)	89 10	89 14	89 11
: (720)	80 39½	—	80 42	(001) : ($\bar{1}$21)	51 57	51 58	51 56
: (100)	90 0	90 0	90 0	: ($\bar{1}$20)	90 50	90 46	90 49
Zone [010,201].				Zone [001,210].			
(010) : (211)	76 43	76 17	—	(001) : (212)	40 2	40 6	40 4
: (201)	90 0	90 0	—	: (211)	58 48	58 55	58 45
Zone [010,101].				: (210)	88 48	88 43	88 50
(010 : (121)	54 5½	54 3	—	(001) : (212)	41 4	40 37	41 0
: (111)	70 6	70 6	70 5	: (211)	60 40	60 25	60 39
: (212)	79 44½	79 44	79 43	:(210)	91 12	91 7	91 10
: (101)	90 0	—	90 0				

Lengenbachite.

This new mineral occurs in thin blade-shaped crystals, sometimes very thin and curled up like paper; they exhibit a highly perfect cleavage, with splendent lustre, parallel to the large face. One crystal measured 40 mm. in length and 5 mm. in breadth. The common habit is an irregular interlacing of thin plates striated parallel to their length, but frequently I have noticed the union of two or more plates parallel to the cleavage-plane at an angle approximating closely to 60°, on one or both

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sides of the long edge of the plate; also a less common aggregation is one similarly arranged, but making an angle approximating closely to 90°. This twinning (?) about a plane at 45° to the long edges of the crystals is also to be seen in sartorite, rathite, and baumhauerite, crystals of which sometimes cross one another at right angles. A third aggregation is that of two long prisms twinned and combined together about a plane bevelling the edge of the long side of the prism; the reflection from the two cleavage planes of the twinned parts is very good, and the angle measured was 28° 37′.

Some of the crystals exhibit a number of fine striae, which traverse the cleavage-planes and bevelled edges at an angle, on the cleavage-plane, of about 58° with the long edge of the plate; such crystals might easily be mistaken for thin crystals of jordanite.

Various crystal fragments were measured to endeavour to discover the crystallographic system. From the best crystal I obtained in the prism-zone, [*CM*], the angles $CM = 92° 30'$ and $CN = 25° 18'$; for a zone of faces terminating the crystal the angles $Ch = 70° 7'$, $Cg = 81° 32'$, $Cl = 106° 32'$, and $Cm = 121° 0'$; and for other terminal faces not falling into any zone the angles $Cd = 91° 40'$, $Cf = 94° 8'$, $Ca = 60° 4'$. In the prism-zone of another crystal the angles to the cleavage *C* were 85° 12′, 91° 31′, 96° 33′, 98° 6′, and 117° 10′; and in the prism-zones of other crystals 43° 0′ and 58° 35′, 51° 7′ and 57° 12′. The re-entrant angle, $C\overline{C}$, in the prism-zone of a twinned crystal was 28° 37′. As I have been unable to perceive any plane or axis of symmetry present in the crystal fragments measured, I conclude that the system of lengenbachite is anorthic.

I had hoped that the very thin plates, though opaque to light, might have proved transparent to radiant heat[1], and so help to determine the symmetry, but Dr. A. Hutchinson tells me that he finds that they are absolutely opaque to heat-rays.

The plates are flexible, but not elastic; they are somewhat malleable, make a mark on paper, and are difficult to pulverize. The crystals do not fly asunder when heated, as do the other sulpharsenites of lead from the Binnenthal. The specific gravity of 1·3700 gram. of picked plates was found to be 5·80. Lustre, metallic; colour, steel-grey, often with an iridescent tarnish. Opaque. Streak, black, with a chocolate tinge.

A preliminary chemical examination, kindly made by Dr. A. Hutchinson, proves the mineral to be essentially a sulpharsenite of lead with small amounts of silver, copper, and antimony.

[1] See Hutchinson, Min. Mag., 1903, vol. xiii, p. 342.

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For the new mineral described above I propose the name lengenbachite[1], after the Lengenbach, a tributary stream in the Binnenthal, which flows through the dolomite quarry where the crystals were discovered in July, 1904.

Bowmanite.

System: rhombohedral. (111) : (100) = 58° 50′. $a : c = 1 : 1{\cdot}1847$. This element was calculated from (100) : (010) = 88° 48½′, measured on a crystal giving very sharp reflections; another crystal with fairly sharp reflections gave (100) : (111) = 58° 50′.

Forms observed: $o\{111\}$, $r\{100\}$, $f\{\bar{1}11\}$. The common habit is a rosette-like aggregation of a number of thin plates with curved surfaces: the individual crystals are usually six-sided plates parallel to $\{111\}$, and are bounded at the edges by narrow faces of $\{100\}$ and $\{\bar{1}11\}$. Sometimes the crystals resemble octahedra, $\{111\}$ and $\{100\}$ being equally developed: the faces of the form $\{\bar{1}11\}$ are always small, and deeply striated parallel to their intersections with (111).

Colour, honey-yellow. Lustre, brilliant, and vitreous to resinous in character. Streak, white. There is a perfect cleavage parallel to (111)[2]. Hardness, 4½. Specific gravity, 8·2. Transparent; optically uniaxial and positive. Occurs on and among crystals of dolomite in the Lengenbach quarry.

The name bowmanite I have given to this new mineral in honour of Mr. Herbert Lister Bowman, M.A., Demonstrator in Mineralogy in the University of Oxford.

The above description is based on a few small crystals obtained in the summer of 1904; but I have, during the last three years, collected a few small rounded honey-yellow crystals, the faces of which were too irregular and curved to admit of accurate measurement.

The small amount of available material has been handed over to Mr. Bowman for examination. He reports that in some of its characters the new mineral resembles hamlinite, from which, however, it differs

[1] A note on lengenbachite, marrite, and bowmanite was read at the Cambridge meeting of the British Association in August, 1904, and these names were first published in 'Nature' on December 1, 1904 (vol. lxxi, p. 118).

Amongst a series of Binnenthal minerals exhibited at a meeting of the Vienna Mineralogical Society on November 7, 1904, were specimens of a new and undescribed species to which the name jentschite was applied. So far as can be judged from the brief description of the exhibits, as reported in Tschermak's Mitteilungen (1904, vol. xxiii, p. 551), jentschite would appear to be identical with the mineral described above under the name lengenbachite. In the same place brief mention is also made of some new minerals under the names hutchinsonite and trechmannite.

[2] Not (100), as stated in 'Nature,' 1904, vol. lxxi, p. 118.

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in composition, being essentially a phosphate of lime and alumina, with small amounts of iron, water, and possibly magnesia.

He finds, further, that the crystals are pseudosymmetric, and show, through thin plates cleaved parallel to the basal plane, a division into six biaxial sectors, in which the acute bisectrix is normal to the surface, the axial plane nearly at right angles to the adjacent edge of the hexagonal plate, and the birefringence positive and rather strong. The axial angle varies, in some cases reaching a value $2E = 50°$, while some of the crystals are uniformly uniaxial, without sectors.

It is hoped that more material will soon be found, so that the composition and characters of the mineral may be more completely determined.

APPENDIX.

Blende with metallic lustre, from the Binnenthal.

These highly modified and twinned crystals of tetrahedral habit were found in 1904 in the slate-coloured dolomite of the Lengenbach quarry. They are especially interesting on account of the very thin and highly brilliant, metallic [1], lead-grey coating by which they are enveloped; this surface film becomes dull when exposed to the light, and disappears rapidly in the presence of hydrochloric acid. The crystals might easily be mistaken for galena or tennantite.

According to Becke [2], the largely developed octant of the Lengenbach blende is $\{1\bar{1}1\}$, and this orientation of the crystals is here adopted. With the exception of a small tetrahedral face (111), all the forms on these crystals lie in the negative octants.

The following table of calculated and measured angles between the faces of the three crystals (I, II, III) contains five new forms marked *.

	Calculated.	Measured. I.	II.	III.
(100) : $(6\bar{1}1)$*	18°16′	18°14′	18°16′	—
: $(4\bar{1}1)$	19 28	19 26	—	—
: $(2\bar{1}1)$	35 16	35 16	35 16	35°16′
: $(7\bar{4}4)$	38 56½	—	39 0	—
: (11.7.7)*	41 59	41 59	42 0	41 58
: $(7\bar{5}5)$*	45 17	45 14	—	45 17
: $(18.\bar{1}0.10)$*	47 24½	—	—	47 17
: $(5\bar{4}4)$*	48 31½	48 28	48 30	—
: $(1\bar{1}1)$	54 44	54 44	54 44	54 44
: (110)	90 0	—	90 0	—

[1] Crystals of blende with metallic lustre have been described by Professor Miers, Min. Mag., 1899, vol. xii, p. 111. [2] Min. petr. Mitt. (Tschermak), 1888, vol. v, p. 507.

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Seligmannite [1].

In October, 1904, some comparatively large (measuring 2·5 × 2 × 1 mm.) black, much twinned crystals of this very rare mineral were found. They are deposited on large crystals of dufrenoysite, and also on baumhauerite. Mingled with the seligmannite, and partially coating the baumhauerite, are a number of very fine needles of a lead-grey colour, the nature of which I have as yet been unable to determine.

Montreux Club,
Territet, Switzerland.

[1] Cf. Min. Mag., 1903, vol. xiii, p. 336.

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An improved form of Refractometer.

By G. F. Herbert Smith, M.A., F.G.S.
Assistant in the Mineral Department of the British Museum.

[Read June 7 and November 15, 1904.]

THE first form of refractometer, in which a reference-scale was substituted for the rotational parts and graduated circles of the more complex instruments, was designed in 1885 by Professor E. Bertrand[1], who at the same time was the first to suggest the employment of a hemisphere of dense glass in place of the prism and cylinder previously used. The original instrument and others on the same principle which have hitherto been constructed do not give satisfactory results, because no attempt has been made to compensate for the curvature of the focal surface of the hemisphere, and the determinations obtained are, therefore, far from trustworthy. In the refractometer described in this paper a corrective lens is placed in the path of the rays emerging from the hemisphere, and the field thus produced is rendered very nearly plane.

For a particular substance in contact with the plane surface of the hemisphere the angle of total-reflection is $\sin^{-1}\frac{\mu}{\mu_0}$, where μ and μ_0 are the refractive indices of the substance and the glass respectively. At any point on the plane the limiting rays of total-reflection form a cone, the axis of which is normal to the plane and the vertical angle double of that of total-reflection. If the effects of spherical and chromatic aberrations be neglected, the rays parallel to any particular ray of the cone come to focus at a point which lies on the ray passing through the centre of the spherical surface at a distance $\frac{\mu}{\mu-1}.r$ from the centre, where r is the radius of the hemisphere. The focal surface, therefore, for all angles of total-reflection is part of a sphere concentric with the glass hemisphere and of radius $\frac{\mu}{\mu-1}.r$. The rays for any particular angle of total-reflection come to focus on a small circle, forming the intersection of the sphere with the cone mentioned above. Since it is impossible for

[1] Bull. Soc. Min. France, 1885, vol. viii, pp. 375–377.

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a plane to coincide with a spherical surface, accurate readings are out of the question owing to the bad definition of the edge of the shadow and the uncertainty of its true position owing to the effects of parallax.

It is necessary, therefore, to compensate in some way for the curvature of the focal field. After a few experiments the author found that adequate compensation was obtained by the interposition of a convex lens of suitable focal length in the path of the rays emerging from the hemisphere. The problem is, indeed, to bring light which is parallel within the glass to focus in a flat field, and is the same as the construction of a telescope in which the field-lens of the objective is a hemisphere of dense glass, the plane surface being turned outwards, and in which the angular width of the field is about 30°. The simplest and

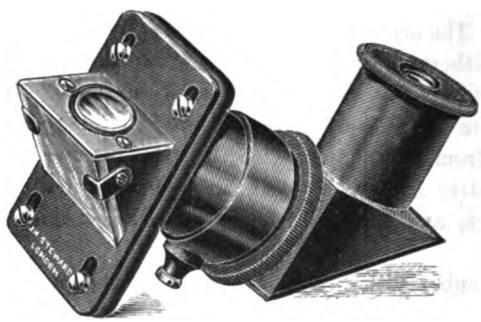

Fig. 1.—Refractometer (actual size).

most convenient method of testing the efficiency of any corrective lens is to employ it in conjunction with the hemisphere as the objective of such a telescope. The author found that, if the hemisphere, 10 mm. in diameter, be composed of glass, the refractive index of which for the D lines is 1·7938, a convex lens of crown glass and focal length 18 mm., placed with the surface of greater curvature almost in contact with the hemisphere, gave satisfactory results, and that, when this combination is employed as a total-reflectometer, the edges separating the light and dark fields are sharply defined throughout the whole of the effective range of the instrument. For reasons stated above the edges appear as circular arcs. If, however, the hemisphere and convex lens be replaced by a semi-cylinder and a cylindrical lens respectively, the sections of the latter pair perpendicular to their geometrical axes being identical with the central sections of the former pair, the edges become straight

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lines; it is important that the axes of the cylinders should be truly parallel.

The illustration (fig. 1) shows the construction of the instrument. The hemisphere of dense glass, the refractive index of which is 1·7988, is firmly embedded in a thin, brass plate, which is attached by screws to two shoulders rigidly connected to a vertical brass plate. The hemisphere is inclined in such a position that the angle between the perpendicular to its plane surface and the axis of the tube of the instrument is about 64°, and thus the centre of the field corresponds to a refractive index of 1·61. The plate of ground-glass is equally inclined to the vertical plate, but in the converse sense. Four screws passing through slots in the vertical plate connect it with a similar plate terminating the tube, and thus an adjustment of the centre of the plane surface of the hemisphere is provided with regard to the axis of the tube. At the end of this tube is placed the corrective lens, the surface of greater curvature being almost in contact with the hemisphere and its optic axis coinciding with the axis of the tube. The clamp at the other end grips an inner tube carrying at its inner extremity a thin, glass plate on which a scale, figured at every tenth division (fig. 2), has been photographed. Inside the inner tube slides a positive eye-piece, in which a totally-reflecting prism is interposed between the two lenses for greater convenience in taking observations.

Fig. 2.—Scale with shadow-edges.

The effective range of the instrument is from about 1·40 to 1·76. Each interval on the scale corresponds to a difference of refractive index varying from 0·007 in the higher to 0·015 in the lower indices. If sodium-light be the source of illumination the edge separating the light and dark fields appears as a delicately traced line and is so well defined that a practised eye can estimate the tenths of divisions, and thus measurements may be carried to one or two units in the third place of decimals. The scale is calibrated for this light by means of observations made on a few substances of known refractive power. If white light be used the edge is no longer a line but a spectrum, in which case the position corresponding to the yellow portion should be noted. The value thus obtained will be accurate to units in the second place of decimals at least, and will be sufficient for most determinative purposes. The width of the spectrum measures the amount of chromatic dispersion

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displayed by the substance under examination. With this instrument accurate measurements may be made of the refractive power of fragments so small as 1 mm. in diameter.

The refractometer has been constructed by Mr. J. H. Steward, the well-known optician of London, whose keen interest in the development of the instrument and zealous assistance in the preliminary experimental work it affords the author much pleasure to acknowledge.

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On some new forms of Quartz-wedge and their uses.

By JOHN W. EVANS, LL.B., D.Sc., F.G.S.

Mineralogist to the Scientific and Technical Department of the Imperial Institute.

[Read November 15, 1904.]

THE determination of the amount and sign of the relative retardation of the wave-fronts of the two rays, into which a plane-polarized ray of light is resolved in passing through an anisotropic crystal, furnishes us with the readiest means of identifying transparent minerals occurring in thin sections or as minute fragments without definite crystalline form. In sections which are of practically the same thickness the individual crystals of each mineral show a certain range of colours resulting from the interference of the rays after resolution parallel to the principal plane of the analyser, and these colours are usually sufficient, with the help of other characters, for the identification of the mineral species. But when the thickness of the micro-sections varies considerably, or we are dealing with small grains from river sand or fragments resulting from the crushing of a rock, the problem is less simple, and quantitative determinations are required.

Every ray passing through a substance suffers retardation, that is to say, travels a less distance than it would traverse in the same time in vacuo. The retardation r_1 suffered by a ray of light in traversing a unit of distance in any isotropic substance is $\frac{v}{v_1} - 1$, where v is the velocity in vacuo and v_1 the velocity in the substance, for $\frac{v}{v_1}$ is the distance the light would have gone in vacuo in the same time as it occupied in traversing one unit of distance in the substance.

But $\frac{v}{v_1} = \frac{1}{u_1} = \mu_1$, where u_1 is the velocity in the substance, taking the velocity in vacuo as unity, and μ_1 is the index of refraction in the substance. Accordingly, we have

$$r_1 = \frac{v}{v_1} - 1 = \frac{1}{v_1} - 1 = \mu_1 - 1.$$

The quantity r_1, the retardation in a unit of length, may be termed the index of retardation.

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In the case of light, travelling in a given direction, entering an anisotropic substance it is resolved in general into two rays propagated at different rates. If the wave-fronts of these rays have velocities v_1 and v_2, or, taking the velocity in vacuo as unity, u_1 and u_2, and their indices of refraction are μ_1 and μ_2, and indices of retardation r_1 and r_2,

$$r_1 = \frac{v}{v_1} - 1 = \frac{1}{u_1} - 1 = \mu_1 - 1,$$

and

$$r_2 = \frac{v}{v_2} \quad 1 = \frac{1}{u_2} - 1 = \mu_2 - 1.$$

If d be the difference in the retardation of the two wave-fronts in a unit of length parallel to the wave-normals [1],

$$d = r_1 - r_2 = \frac{1}{u_1} - \frac{1}{u_2} = \mu_1 - \mu_2.$$

The quantity d is usually known as the strength of double refraction, or birefringence, but it is better described as the relative retardation in a unit of length, or the index of relative retardation.

If, instead of a unit length, a distance l be traversed parallel to the wave-normals in the anisotropic medium and k be the total relative retardation of the two wave-fronts in passing through that distance, we have

$$k = ld.$$

For instance, if a thin section of quartz be cut parallel to the axis, the index of relative retardation (birefringence) of light traversing it approximately at right angles will be 0·0091 (for sodium-light): then if the thickness of the section be 0·023 mm. we have

$$k = 0{\cdot}023 \times 0{\cdot}0091 = 0{\cdot}000209.$$

It is, however, usual to take as the unit of relative retardation a micromillimetre, or millionth part of a millimetre, as by so doing numerous decimal places are avoided. This unit is, however, too small for measuring the thickness of thin plates and small crystals, and I have found it convenient to take as unit of thickness a thousandth part of a millimetre, viz. a thousand micromillimetres. The relative retardation in micromillimetres in traversing this distance will be a thousand times that in traversing a micromillimetre, that is, a thousand times the absolute index of relative retardation or birefringence; and it is free from the disadvantage of being a small fraction of unity.

[1] Strictly speaking the wave-fronts will be parallel only if the ray meets a plane surfaceof the anisotropic medium at right angles.

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If then

K = relative retardation in micromillimetres,

L = thickness in thousandths of a millimetre,

D = relative retardation in micromillimetres in traversing one thousandth part of a millimetre

$$= 1000\,d = 1000\left(\frac{1}{u_1} - \frac{1}{u_2}\right) = 1000\,(\mu_1 - \mu_2),$$

we have

$$K = LD.$$

D may be considered a working index of relative retardation one thousand times the absolute index. The calculation given above then becomes

$$K = 23 \times 9{\cdot}1 = 209.$$

To ascertain the index of relative retardation in any particular direction in a crystal it is, therefore, sufficient to know the thickness of the crystal in the direction in question and the relative retardation that takes place in that distance [1]. The latter is approximately determined by reference to a scale of Newton's colours, either in a coloured plate or expressed in words. In neither case are very satisfactory results obtained, especially when the colours become fainter or entirely disappear as the relative retardation increases. By the use, however, of the quartz-wedge inserted in the position of compensation [2] it is possible, when the relative retardation is not too great, to determine to which of the orders in Newton's scale the colour belongs.

To secure more exact determinations of the relative retardation various means have been employed, among which may be mentioned the bifractometer, the Babinet compensator, and the twin-compensator. These are, however, complicated pieces of apparatus, designed rather for the determination of physical constants than for the identification of small mineral particles.

In the laboratory of the Scientific and Technical Department of the Imperial Institute it is frequently necessary to recognize small sand-grains and fragments of crushed rock or veinstuff, and for this purpose a quartz-wedge, that has been made under my directions by Messrs. R. & J. Beck, Ltd., has proved very useful.

Its angle is much larger than that of wedges ordinarily in use, the maximum thickness being as much as a millimetre and a half. It is

[1] See Mallard, Traité de Cristallographie, Paris, 1884, vol. ii, p. 399.

[2] For this purpose it is best placed in the focus of the eye-piece, a microscope being employed in which the analyser is above the eye piece.

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graduated so as to show the relative retardation of light passing through it at different points, the relative retardation at two adjoining divisions differing by a thousand micromillimetres. The divisions were fixed by ascertaining with a micrometer-screw the points at which the thickness amounted to multiples of $\frac{1000}{9{\cdot}1}$ thousandths of a millimetre [1]. I calibrated the wedge by placing it in sodium-light, first between crossed nicols, when the dark bands gave the points where the relative retardation amounted to an even number of semi-wave lengths, and then between parallel nicols, when similar bands gave the points where it amounted to an odd number of semi-wave lengths. The average difference of relative retardation between adjacent lines was thus calculated to be 999·6 micromillimetres.

With this wedge relative retardations up to 14,000 units (about twenty-eight 'orders' of colours) could be observed. A still thicker wedge is, however, sometimes needed.

In determining the index of relative retardation in small fragments they are immersed in a liquid of sufficiently high index of refraction to render them fairly transparent. The thickness is then determined by using a high power and focusing with the fine adjustment, which should be graduated in thousandths of a millimetre, first on an edge or crack on the top of the fragment and then on a scratch in the glass-slip on which it lies. This apparent thickness multiplied by the index of refraction of the liquid gives the real thickness of the fragment [2].

The relative retardation of light traversing the fragment is measured by inserting the wedge in the position of compensation till the dark band representing complete compensation is reached. The relative retardation is then read off directly from the wedge, amounts of less than a thousand micromillimetres being estimated from the position between the two nearest graduations.

If the surface of the fragment is irregular, coloured bands are seen, which are mainly due to the variation in the thickness of the fragment.

[1] The graduations of the 'birefractometer' represent the thickness in decimal parts of a millimetre, not the relative retardation.

[2] The focus is best determined by using a strong monochromatic light passing through a small aperture six inches at least from the mirror of the microscope. Interference rings are formed unless the focus is very exact (see Lévy and Lacroix, 'Les Minéraux des Roches,' Paris, 1888, p. 60). The thickness may also be measured through the mineral and multiplied by its approximate index of refraction as estimated by Becke's method. This usually gives a sufficiently approximate value for the index of relative retardation to enable the mineral to be identified.

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Some particular point in the crystal must accordingly be chosen for the determination both of the thickness and relative retardation.

If the index of relative retardation of the crystal is very high the bands are sometimes so narrow that it is difficult to distinguish the colours, and these are often appreciably modified by the variations in the index for different parts of the spectrum. An approximate result can then be obtained by observing the reading on the wedge when the bands begin to be visible in the part of the fragment selected for the observation, and the reading when they disappear; the mean of these readings will give with close approximation the relative retardation.

If a high power be used in determining the relative retardation the cone of light should be narrowed either by lowering the condenser or by the use of a diaphragm, so that the colours or bands may be more clearly visible.

For the determination of the index of relative retardation of minerals in thin sections, which show colours corresponding to comparatively low relative retardation, I find it convenient to use a double quartz-wedge[1], which I have also had made by Messrs. R. & J. Beck, Ltd., for the Imperial Institute. It consists of two quartz-wedges placed close together, side by side. One is cut in the usual manner with its length parallel to the vertical axis of the crystal, the other with its breadth parallel to the same direction, so that when placed with their lengths parallel they have their axes at right angles and therefore extinguish simultaneously between crossed nicols. They are ground down together to the same slope, and when placed obliquely between crossed or parallel nicols they show exactly the same bands of colour, which pass continuously across both wedges. If now a crystal-plate is also placed in the position of extinction between the crossed or parallel nicols, the two wedges continue to show the same colours; but if, by the rotation of the crystal or of the nicols and double wedge together, the directions of extinction of the crystal are parallel to those of the double quartz-wedge and make an angle of 45° with the nicols, one of the wedges will show a black band indicating the position of compensation, while the second will show colours corresponding to increased relative retardation. It is evident that the colour, which on the latter wedge is opposite the centre of the dark band of the former, denotes a relative retardation exactly double that of the crystal-plate alone, and thus a more accurate determination of the relative retardation of the plate may be made. Either the relative

[1] I find that somewhat the same principle has been applied in a different manner in the twin-compensator.

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retardation corresponding to the colour opposite to the centre of the dark band should be divided by two; or, better, the colour on one wedge opposite to a sensitive tint (*teinte sensible*) on the other should be noted, and the difference of the relative retardations corresponding to these colours, or the sum of those relative retardations if one of the colours is between the dark band and the thin end of the wedge, should be halved in like manner. Additional accuracy can be obtained by making several similar observations with crossed and parallel nicols. With low relative retardations parallel nicols usually show more distinctive tints.

The double wedge is also more convenient than the single wedge for determining the sign of a direction of extinction in a mineral in a thin section, for a comparison of the two sides tells clearly and at once which shows compensation and which addition.

It can also be used as a stauroscope; for, if a crystal-plate is rotated between crossed or parallel nicols with the double wedge at 45° to them, or the nicols and wedge are rotated together, the crystal being stationary, the position of extinction is known by the exact correspondence of the bands on the two wedges.

It is scarcely necessary to add that, as pointed out by Mallard and by Lévy and Lacroix[1], the thickness of a section may be determined by observing which of a number of individuals of some known mineral has the colour representing the greatest amount of relative retardation. It may then be assumed that this individual is cut so that the velocities of the two wave-fronts of light propagated transversely to the section are approximately the same as the greatest and least velocities in the mineral, and that the index of relative retardation at right angles to the section is nearly equal to the maximum index of relative retardation in the crystal; the latter being the difference between the greatest and least retardations, or, what is the same thing, the difference between the greatest and least indices of refraction—or a thousand times this amount if the working index of relative retardation, which I have suggested, is employed in place of the absolute index.

We can now calculate the thickness of the section at once from the formula $K = LD$, where K is the observed relative retardation in millimetres, $D = 1000\,(\gamma - \alpha) = 1000\left(\frac{1}{u_\gamma} - \frac{1}{u_\alpha}\right)$, and L is the thickness in thousandth parts of a millimetre.

[1] loc. cit.

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Note on some new localities for Gyrolite and Tobermorite.

By James Currie, M.A., F.R.S.E.

[Read November 15, 1904.]

SINCE the mineral gyrolite was described and analysed by Anderson from Storr in Skye in 1851, it has been recorded from a considerable number of other places in that island. The writer observed it at the mouth of the burn called Allt Mòr, between Loch Brittle and Loch Eynort, and has now to record it from Rudha nan Clach at the mouth of Loch Bracadale, which brings the number of localities at present known in Skye up to fourteen. In fact, the mineral may be said to occur all along the south-western shore, all along the eastern escarpment, and at the more isolated localities of Lyndale and Portree. Similarly, it occurs in the other trap islands—the Treshnish group, Mull, Muck[1], Eigg, Canna, and Sanday, upon the last of which it has been observed by the writer at Stac nan Faoilean. In all, we have now some thirty localities in the Western Islands of Scotland; so that, although very seldom found in fine specimens, gyrolite may be said to be a characteristic mineral of the denser igneous rocks of the Hebrides.

It has not hitherto been recorded[2] from the mainland of Scotland; but the writer recently observed it in Argyllshire. The line of trap cliff, which stretches south from Ardtornish Bay in Morvern until it is cut off by the fault of the Dearg Allt, surmounts a steep talus overgrown with grass and clothed with bracken and low wood. There are few screes and the rock is much weathered and moss-covered. It is not markedly amygdaloidal, but occasionally analcime upon mesolite may be observed. In the harder and more basaltic rock the steam cavities are small and rare. When they do occur they are generally filled with gyrolite.

Very rarely the druses of the Ardtornish basalt are filled with reddish-white, massive tobermorite, apparently upon mesolite. The species tobermorite has also not been hitherto observed upon the mainland. It has been recorded by Heddle[3] from Tobermory and Bloody Bay in Mull

[1] M. F. Heddle, 'The Mineralogy of Scotland,' 1901, vol. ii, p. 98.

[2] A reported occurrence in Stirlingshire was shown by Lacroix to refer probably to thomsonite (Bull. Soc. franç. Min., 1887, vol. x, p. 148).

[3] 'The Mineralogy of Scotland,' 1901, vol. ii, p. 88.

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and from Dunvegan in Skye. Sgùrr nam Boc in the latter island should also have been given [1]. On the other hand tobermorite with analcime is mentioned in 'The Mineralogy of Scotland' as associated with the gyrolite of Beinn na Croise in Mull by an error in the transcription of the MS., which has transferred these minerals from the locality immediately following. They really belong to Bloody Bay [2].

The only other mineral in the rock at Ardtornish is yellowish-green olivine in small nodules of 3 to 4 mm. in diameter.

In every case, so far as the writer knows, the Scottish gyrolites occupy the infrequent druses of dense Tertiary basalts, and are generally solitary. The only common associate is the closely allied mineral apophyllite.

The mode of occurrence in Scotland does not lend any support to Professor How's supposition that gyrolite owes its origin to the decomposition of apophyllite. In fact when they occur together the apophyllite in Scotland seems invariably to overlie the gyrolite, as it does in California, so that in these cases it would be more reasonable to derive the former mineral from the latter. But in specimens freshly extracted from the rock both minerals appear perfectly unaltered, and there does not seem to be any ground whatever for the supposition that either is formed at the expense of the other. It is curious that if How's statement [3] be correct, the order of deposition in Nova Scotia is the reverse of that observed in Scotland, while in California we again have the gyrolite as the older mineral.

Gyrolite was some time ago recorded by Professor Heddle from the Færöes, his locality being Kodlen in Osterö. It has been observed by the writer at three other localities, all of them in the island of Stromö. These are the shore of Leinum Vatn (sometimes called Store Vatn); Vestmannhavn; and Sundelaget, at the narrowest part of the strait between the two principal islands.

At the last-named locality the gyrolite, here associated with small superimposed crystals of apophyllite in the combination *a c*, sometimes overlies a massive, white mineral with a minutely mamillated surface, which, so far as can be judged without analysis, is identical with tobermorite.

Professor Heddle [4] further identified with gyrolite the 'micaceous

[1] See Heddle, Trans. Geol. Soc. Glasgow, 1892, vol. ix, p. 254.
[2] Cf. 'The Mineralogy of Scotland,' 1901, vol. ii, p. 92.
[3] Edinburgh N. Phil. Journ., 1861, vol. xiv, p. 117.
[4] 'The Mineralogy of Scotland,' 1901, vol. ii, p. 79.

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zeolite' of Giesecke from Niakornak, which of course is not upon Disco Island as stated by Haidinger, but upon the south shore of Umanak Fjord in Greenland. Giesecke in his diary[1] says that the 'faserigen Mesotyp ... geht oft ins krummblätterige über, ist schiefrig, hat einen starken Perlenmutter-, oft beinahe metallischen (Silber-) Glanz, und braust etwas mit Salpetersäure [probably from calcite present as an impurity]. Seine Krystallisation scheint die sechsseitige Tafel zu sein.' Elsewhere he calls this mineral 'Glimmerzeolith,' and at Tupausarsuit[2] connects it with the accompanying apophyllite. Both minerals also occur at Tarajungitsok in Disco Fjord[3]. Perhaps gyrolite is also indicated by the 'massive apophyllite' and 'pearl-white radiated mesole' of Akkiarut[4]. Although they are really very distinct in appearance, it is by no means always easy to decide whether faröelite or gyrolite is intended by the 'mesole' of some of the older writers.

It is interesting to note that Sir Charles Giesecke records as accompanying the apophyllite and gyrolite of Tupausarsuit a 'pale red massive zeolite[5],' which we may probably infer to be tobermorite.

[1] F. Johnstrup, 'Gieseckes mineralogiske Rejse i Grønland,' Kjøbenhavn, 1878, p. 245.

[2] loc. cit., p. 255.

[3] loc. cit., p. 329.

[4] C. L. Giesecke, 'A descriptive catalogue of a ... collection of Minerals in the Museum of the Royal Dublin Society,' Dublin, 1832, pp. 54, 55.

[5] loc. cit. (Diary), p. 255.

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Note on the occurrence of Brookite in the Cleveland ironstone.

By C. R. Lindsey, B.Sc.

[Read November 15, 1904.]

THE references to the occurrence of the titanium dioxide minerals as rock constituents have been so recently summarized in the 'Mineralogical Magazine[1]' that it is unnecessary to repeat them, except to refer again to Mr. J. J. H. Teall's record of anatase in the Cleveland ironstone[2].

Wishing to procure some of these crystals, a pound of ore from the Main Seam at Upleatham mines was treated by the usual processes of solution, washing by decantation, and separation by heavy solution. The residue obtained was equal to 0·16 per cent. of the material taken, and consisted mainly of anatase, mostly in sharply developed pyramidal crystals, with some pyrites in nodular concretions, possibly in replacement of some of the oolitic grains, together with other minerals of derived origin, among which rutile and tourmaline were the most prominent.

But, most interesting, were a considerable number of crystals of brookite. This occurred in two forms:—

1. Thick, tabular crystals of deep reddish-brown colour, averaging about one-eighth of a millimetre in length by about one-fourth of that amount in breadth, though they sink to much smaller dimensions. They are occasionally doubly terminated, but usually show one end only with crystal-faces (figs. 1, 2, 3), the other end being broken off, or still attached to the material from which the crystals appear to have originated. In convergent polarized light the crystals well show the characteristic crossing of the optic axial planes for blue and red light. The absorption for light rays vibrating across the crystals is distinctly less than for those vibrating parallel to the length of the crystals.

2. The other habit in which the crystals occur is in extremely thin plates of the forms shown in figs. 4, 5, 6, 7. The external boundaries, as well as the lines marking the edges of the parallel growths, are very sharply

[1] J. B. Scrivenor, 1903, vol. xiii, p. 348.

[2] 'British Petrography,' 1888, plate 44, fig. 6, but not referred to in the text. The occurrence of anatase in the Cleveland ironstone was earlier noted by Mr. Allan B. Dick, and the crystals were measured by Professor W. H. Miller ('The iron ores of Great Britain,' Mem. Geol. Survey, 1856, p. 95).

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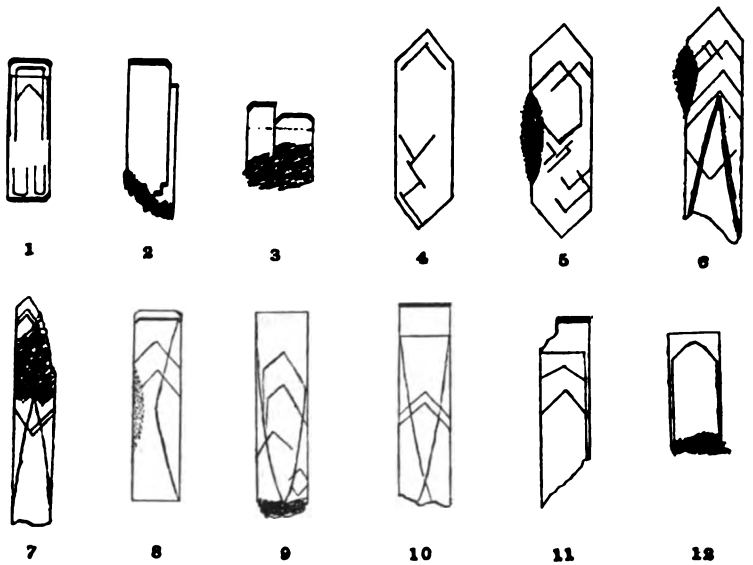
defined. A few crystals are doubly terminated, but mostly they show only one termination, the edges of which meet at an acute angle; this angle has been measured in numerous cases, giving, e.g., 79½°, 80°, 81½°, 81°, 82°, 82°, 81°, so that, allowing for the fact that the crystals may not lie quite perpendicularly to the direction of vision, the angle appears



Crystals of brookite isolated from the Cleveland ironstone.

Fig. 1. Size of crystal: 0·100 × 0·025 mm. The central area is almost opaque.
Fig. 2. Size: 0·125 × 0·035 mm. Colour, deep reddish-brown.
Fig. 3. Crystal with lighter coloured extremity (above the dotted line).
Fig. 4. Size: 0·125 × 0·035 mm. Fig. 5. Size: 0·135 × 0·033 mm.
Fig. 9. Size: 0·245 × 0·042 mm. Fig. 10. Size: 0·108 × 0·025 mm.

(The slides from which these figures were drawn have been deposited in the mineral collection of the British Museum.)

to be about 82°. One crystal showed an obtuse termination of about 119° (fig. 11), while another showed one bounded by both forms in combination (fig. 12). The termination of 82° corresponds approximately with {065} or {*h*65}, and that of 119° with {035} or {*h*35}, but none of these are given in any recorded list of forms of brookite, though one of Thürach's figures[1] seems to have an angle identical with the acute one here mentioned. They polarize in bright colours, sometimes as low as

[1] The middle figure on p. 190 of Rosenbusch-Iddings, 'Microscopical Physiography of the Rock-making Minerals,' first edition, 1888.

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those of the second order, but usually in the third and upwards; compensation takes place when the quartz-wedge is parallel to the length of the crystal. Pleochroism is slight, but distinct, the colour being reddish-brown for vibrations parallel to the length of the crystals, and yellowish-brown in the direction at right angles. There is frequently a darker core, like a rather lengthened 'hour-glass' (figs. 6–10); and the end is often of lighter colour than the rest of the crystal (fig. 8), even when this is not caused by differing thickness.

So far, I have been unable to obtain, with crystals of the second habit, a quite satisfactory figure in convergent polarized light, the nearest approach being a division of the field into indistinct areas of blue and red in their proper positions. But as to the identity of the two kinds of crystals I think there can be no doubt, for not only do these thinner crystals show all the other properties of brookite, but crystals occur which combine the forms of both, i. e., they have the rectangular termination of the one kind overlaid in parallel growth by the pointed form of the other (figs. 1 and 8–12).

In the hope that a fortunate chance might show the relation of the brookite to the anatase, three thin sections of the ironstone were prepared, but they yielded only negative results.

It may be mentioned that the now worked-out magnetite ore of Rosedale, in Yorkshire, yielded no brookite; that here the anatase occurred almost wholly in tabular crystals (parallel to the basal plane); and that, as in the other case, rutile occurred as a detrital constituent both in simple crystals and in twins.

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The Construction of Crystallographic Projections.

By HAROLD HILTON, M.A.
Fellow of Magdalen College, Oxford.

[Communicated by Professor Miers, and read November 15, 1904.]

§ 1. IT is proposed in this paper to describe some simple graphical constructions of theoretical or practical interest. They may be easily performed with ruler and compasses, though the stereographic and gnomonic nets[1] will often save labour. To economize space the proofs of the constructions are left to the reader.

§ 2. First take the case of the gnomonic projection. Given the projections A, B, C, Q (fig. 1) of the poles of the faces (100), (010), (001), (111); find the projection of the pole of any other face (hkl).

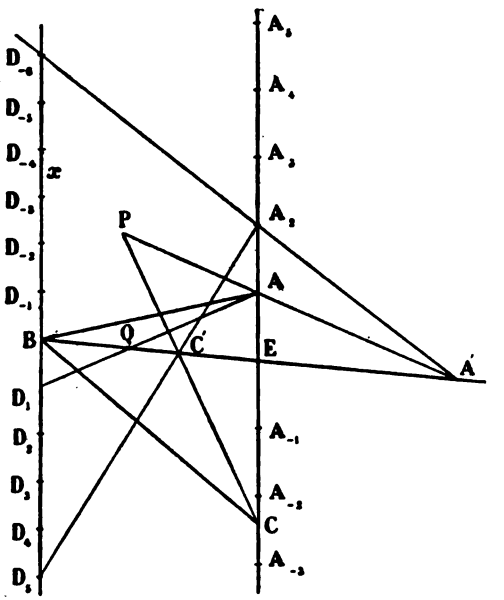

Fig. 1.

Through B draw a line x parallel to AC. Let AQ meet x in D_1, and let BQ meet CA in E. Divide x into equal intervals . . ., $D_{-2}D_{-1}$, $D_{-1}B$, BD_1, D_1D_2, D_2D_3, . . . and CA into equal intervals . . ., $A_{-2}A_{-1}$, $A_{-1}E$, EA, AA_2, A_2A_3, ... Plot the intersections A', C' of BE with A_1D_1, A_3D_3 respectively, and the intersection P of AA', CC' (A_1 coincides with A and D_0 with B). P is the point required; for it may readily be shown that the triliteral coordinates of P are (h, k, l), if the coordinates of Q are $(1, 1, 1)$[2]. In the diagram, P is the projection of the pole of (526).

[1] See Zeits. Kryst. Min., 1902, vol. xxxvi, p. 14; Min. Mag., 1904, vol. xiv, p. 18.
[2] See p. 104.

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The construction holds if h or $l=0$, but not if $k=0$. If $k=0$, we may draw a line through C parallel to AB and proceed similarly; or we may find the projection R of the pole of $(hk'l)$, where $k' \neq 0$, and produce BR to cut CA in the required point.

If Q were the projection of the pole of (uvw) instead of (111), we should take A_{vwl} instead of A_h, D_{wul} instead of D_l, and D_{vuh} instead of D_h.

More generally, if A, B, C, Q are the projections of the poles of $(h_1k_1l_1)$, $(h_2k_2l_2)$, $(h_3k_3l_3)$, $(h_4k_4l_4)$ instead of (100), (010), (001), (111), we replace h, k, l respectively by $M_2M_3\mu_1$, $M_3M_1\mu_2$, $M_1M_2\mu_3$; where M_1, M_2, M_3 are the cofactors of m_1, m_2, m_3 in the determinant $[h_1k_2l_3m_4]$, and μ_1, μ_2, μ_3 are the cofactors of m_1, m_2, m_3 in the determinant $[hk_1l_2m_3]$.

§ 3. Again, joining the points A, B, C, Q in every possible way we obtain the projections of zones meeting in points which are the projections of poles of crystal-faces. Joining these points we get the projections of more zones which meet in the projections of more poles; and, proceeding in this way, we get the projection of every possible pole. However, except for the poles of faces with very simple indices, this process is more tedious than the method of § 2.

§ 4. Suppose we wish to find the angle between two faces the projections of whose poles are P and Q.

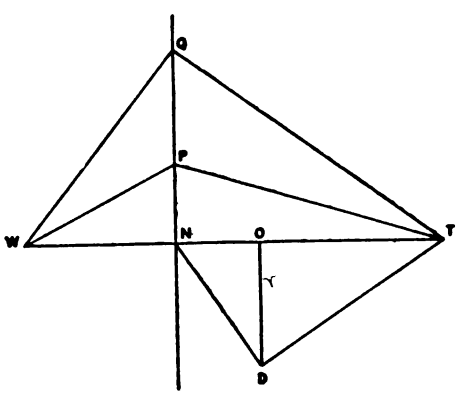

Fig. 2.

Let O (fig. 2) be the centre of the projection and r the radius of the sphere of reference. Draw ON perpendicular to PQ, and draw OD perpendicular to ON and equal to r. Take W on ON such that $NW=ND$.

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Then PWQ is the angle required, since PQ subtends equal angles at W and at the centre of the sphere of reference.

Again, suppose we wish to find the angle between two zones whose projections are TP and TQ. Draw OD perpendicular to TO and equal to r. Draw DN perpendicular to TD. Draw NPQ perpendicular to TN, and take W on TN such that $NW=ND$. Then PWQ is the angle required.

This result is important, for it shows that the gnomonic projection of the poles of a crystal can be readily constructed when we know the angles between its faces and zones; and that, conversely, when we are given the gnomonic projection, we can measure graphically the angles.

The result can be also applied at once to the graphical solution of spherical triangles, &c.

§ 5. Suppose we are given the gnomonic projection P of any pole of a crystal, and we wish to find the projection of the corresponding pole

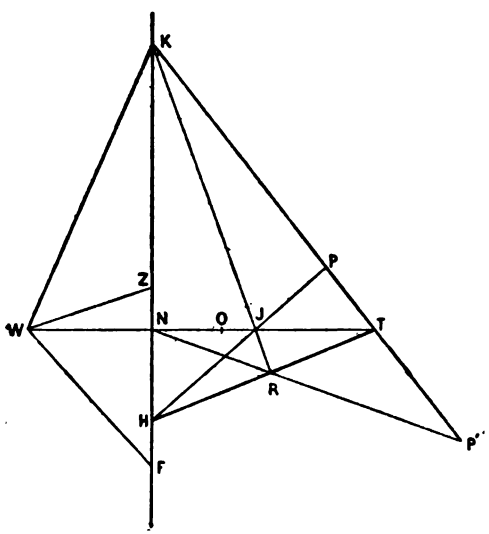

Fig. 3.

of a twin-crystal. Let the crystals be twinned about an axis meeting the plane of projection in T (fig. 3). Produce TO to N so that $TO \cdot ON = r^2$, and draw KNH perpendicular to TN meeting TP in K. Plot the intersection J of TN and HP, the intersection R of KJ and TH and the intersection P' of NR and PT. P' is the point required, since

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the range (PP', KT) is harmonic, and TK subtends a right angle at the centre of the sphere of reference.

The lines TH, TN, HK are drawn once for the whole crystal, and then only one line (TP) has to be drawn for each pole.

§ 6. Suppose now we wish to find the new projection of the pole when the crystal is rotated through an angle α (not $=180°$) about the axis. Take W on TN such that $WN^2 = NO \cdot NT$. Make the angles $KWZ = \alpha$, $KWF = \frac{1}{2}(180° + \alpha)$. Then the point required is the intersection of PF and TZ.

§ 7. We now take the case of the stereographic projection.

It is easy, when we are given the stereographic projection of the zones and poles of a crystal, to find the gnomonic projection on a parallel plane and vice versa. For if the stereographic projection of a zone meets the principal circle j of the projection (whose radius is r and centre O) in E and F, and the tangents at E and F to the projection of the zone meet at S, the gnomonic projection of the zone is the straight line through S perpendicular to OS.

§ 8. Suppose we are given the circle j and the stereographic projections A, B, C, Q of the poles of the faces (100), (010), (001), (111). Let EF be the diameter of j passing through the intersection of BC with the common chord of j and any circle through B and C. Then the circle $BCEF$ is the stereographic projection of the zone [100][1]. We can then by § 7 find the gnomonic projection of the zone [100], and similarly of the zone [0$\bar{1}$1]. Let the straight lines OB, OC meet the former in B', C', and let OA, OQ meet the latter in A', Q'. Then A', B', C', Q' are the gnomonic projections of the poles of (100), (010), (001), (111) respectively. We can therefore find the gnomonic projection of any zone or pole by § 2 or § 3, and then we obtain the stereographic projection by § 7.

§ 9. An alternative to the method of § 8 is the following. Let the stereographic projections of the zones [10$\bar{1}$] and [$\bar{1}$10] meet the circle ABC in B_1 and C_1, and let the straight lines BB_1 and CC_1 meet in Q_1. Let the gnomonic projection of the zone $[HKL]$ for a crystal, such that A, B, C, Q are the gnomonic projections of the poles of (100), (010), (001), (111), meet the circle ABC in X and Y. Then the stereographic projection of the zone $[HKL]$ will pass through X and Y[2].

§ 10. Suppose we are given the stereographic projection P of any

[1] This construction solves the problem: 'Draw a circle through two given points bisecting the circumference of a given circle.'

[2] See Phil. Mag., 1905, ser. 6, vol. ix, p. 87.

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pole of a crystal, and we wish to find the projection P' of the corresponding pole of a twin-crystal. Let T be the projection of the point in which the twinning-axis meets the sphere of reference (whose centre is O and radius is r as before). Draw WOU perpendicular to OT, such that $WO=OU=r$. Then, if the circles WPU, $WP'U$ meet OT in L and L', TW bisects the angle LWL': this gives us the position of the circle $WP'U$. Or, again, if J, S, J' are the centres of the circles WPU, WTU, $WP'U$, SW bisects the angle JWJ'.

The results of the preceding sections hold good in general if we substitute 'extremity of the zonal axis $[hkl]$' for 'pole of the face (hkl)' and 'great circle whose plane is parallel to the face (hkl)' for 'zone $[hkl]$.'

§ 11. We now show how to construct the orthographic projection on a plane Π of a crystal whose faces $f_1, f_2, f_3, \ldots$ are at distances $p_1, p_2, p_3, \ldots$ from the centre C of the crystal. We consider p_1 positive or negative according as the perpendicular from C on f_1 makes an acute or obtuse angle with the perpendicular CO from C on Π; and so for $p_2, p_3, \ldots$. Construct the gnomonic projection of the poles on Π. Let $P_1, P_2, P_3, \ldots$ be the projections of the poles of the faces $f_1, f_2, f_3, \ldots$. Draw P_1Q_1 perpendicular to OP_1 and equal to r. On OQ_1 take $OR_1=p_1$, and draw R_1S_1 perpendicular to OQ_1 meeting OP_1 in S_1. Draw a line l_1 through S_1 perpendicular to OP_1. Construct lines $l_2, l_3, \ldots$ similarly. Then the line through the intersection of l_1 and l_2 perpendicular to the line P_1P_2 is the orthographic projection of the edge in which the faces f_1 and f_2 meet. Similarly we get the orthographic projection of all the edges.

Summary.

In this paper graphical constructions are given for the solution of the following problems:—

Given the gnomonic or stereographic projections of the poles of four faces, find the projection of the pole of any other face.

Given the gnomonic or stereographic projections of the poles of a crystal, find the projections of the poles of a twin-crystal.

Given the projection of two zones, find the angle between them.

Given the gnomonic projection of the poles of a crystal, find the orthographic projections of its edges, &c.

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Some applications of the Gnomonic Projection to Crystallography.

By HAROLD HILTON, M.A.
Fellow of Magdalen College, Oxford.

[Communicated by Professor Miers, and read November 15, 1904.]

1. LET the crystallographic axes OA, OB, OC of a crystal, whose axial ratios are $a:b:c$, meet a plane p in A, B, C. Let a plane through O, parallel to a crystal-face whose indices are h, k, l,

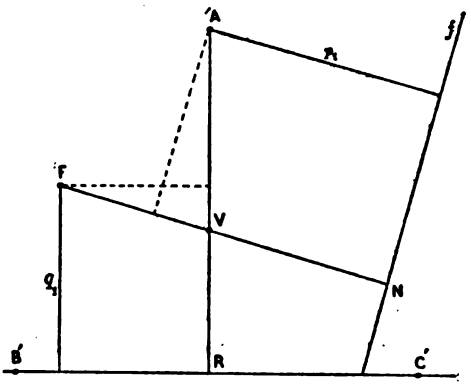

Fig. 1.

meet p in the line f (fig. 1); and let the line OF, perpendicular to the face, meet p at the point F. Let the perpendicular from O on p meet it in V, and let $OV = m$. Let

$$VOA = \alpha, \quad VOB = \beta, \quad VOC = \gamma, \quad FOA = \lambda, \quad FOB = \mu, \quad FOC = \nu,$$
$$VOF = \theta.$$

Then $$h:k:l = a\cos\lambda : b\cos\mu : c\cos\nu.$$

Let FV cut f in N; then FN is perpendicular to f and $FV \cdot VN = m^2$.

Let the perpendiculars from A, B, C on f be p_1, p_2, p_3. Then

$$p_1 = VN + VA\cos AVF.$$

But $$VN = m^2 \div FV = m\cot\theta, \quad VA = m\tan\alpha,$$
$$\cos AVF = (\cos\lambda - \cos\alpha \cdot \cos\theta)\operatorname{cosec}\alpha \cdot \operatorname{cosec}\theta,$$

by spherical trigonometry.

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$$\therefore \quad p_1 = m \cos \lambda \,.\, \sec a \,.\, \operatorname{cosec} \theta,$$

and $$\therefore \quad p_1 a \cos a : p_2 b \cos \beta : p_3 c \cos \gamma = h : k : l.$$

Hence, if we take ABC as triangle of reference in the plane p and suitable triliteral coordinates (xyz), the equation of the line f is

$$hx + ky + lz = 0.$$

The indices of the edge in which the faces (hkl) and $(h'k'l')$ intersect are the same as the coordinates of the intersection of the lines whose triliteral equations are

$$hx + ky + lz = 0 \quad \text{and} \quad h'x + k'y + l'z = 0.$$

Therefore the line through O parallel to the edge $[HKL]$ meets p in the point (HKL).

Let the perpendiculars from O to the faces (100), (010), (001) meet p in $A'B'C'$. Then F is the pole of f, A of $B'C'$, B of $C'A'$, C of $A'B'$ with respect to a circle of radius $\sqrt{-m^2}$ whose centre is V[1]. Let q_1, q_2, q_3 be the perpendiculars from F on the sides of the triangle $A'B'C'$. Produce AV to cut $B'C'$ in R. Then

$$q_1 = VR + VF \cos AVF = m \cos \lambda \,.\, \operatorname{cosec} a \,.\, \sec \theta$$

as before. Therefore

$$q_1 a \sin a : q_2 b \sin \beta : q_3 c \sin \gamma = h : k : l.$$

Hence if we form the gnomonic projection on p of the poles and zones of the crystal which lie on a sphere of radius m whose centre is V, and if we choose a suitable triangle of reference on p and suitable triliteral coordinates, then the point (hkl) is the projection of the pole of the face (hkl) and $Hx + Ky + Lz = 0$ is the projection of the zone $[HKL]$.

The gnomonic projection of the poles and zones on p is the reciprocal polar with respect to a circle of radius $\sqrt{-m^2}$, whose centre is V, of the figure formed by drawing through O planes parallel to the faces cutting p in lines, and lines parallel to the edges cutting p in points.

2. We shall now take illustrations of the use of these theorems.

The anharmonic ratio of four cozonal faces $(h_1k_1l_1)$, $(h_2k_2l_2)$, $(h_3k_3l_3)$, $(h_4k_4l_4)$ is evidently equal to the anharmonic ratio of the range formed by the gnomonic projection of their poles. Now these four poles are the points $(h_1k_1l_1)$, &c., the triangle of reference being suitably chosen, and therefore the anharmonic ratio of the faces is equal to the anharmonic

[1] Since in a plane triangles reciprocal with respect to a circle are homologous, we have incidentally proved that the arcs joining corresponding vertices of a spherical triangle and its polar triangle are concurrent, and that the intersections of corresponding sides of the two triangles lie on a great circle.

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ratio of the pencil formed by the lines joining these points to A', i. e., by the lines $yl_1 = zk_1$, &c. Therefore the anharmonic ratio of the four faces

$$= \left(\frac{k_3}{l_3} - \frac{k_1}{l_1}\right)\left(\frac{k_4}{l_4} - \frac{k_2}{l_2}\right) + \left(\frac{k_4}{l_4} - \frac{k_1}{l_1}\right)\left(\frac{k_3}{l_3} - \frac{k_2}{l_2}\right)$$
$$= (k_1l_3 - k_3l_1)(k_2l_4 - k_4l_2) + (k_1l_4 - k_4l_1)(k_2l_3 - k_3l_2).$$

Again project on to a plane perpendicular to an n-al rotation-axis of the crystal. Let A_1 be the projection of the pole of a face; then $A_2, A_3, A_4, \ldots, A_n$ are also projections of poles, $A_1A_2 \ldots A_n$ being a

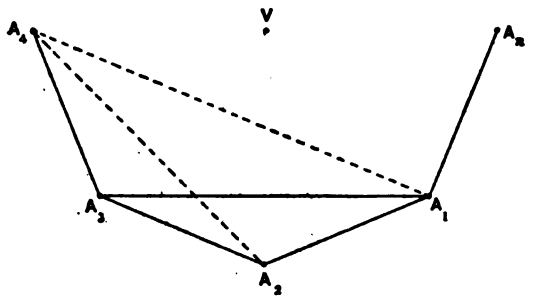

Fig. 2.

regular n-sided polygon (fig. 2). Take $A_1A_2A_3$ as triangle of reference. Then the areal coordinates of A_4 and A_n are

$$\frac{A_2A_3A_4}{A_1A_2A_3}, \frac{A_3A_1A_4}{A_1A_2A_3}, \frac{A_1A_2A_4}{A_1A_2A_3} \text{ and } \frac{A_2A_3A_n}{A_1A_2A_3}, \frac{A_3A_1A_n}{A_1A_2A_3}, \frac{A_1A_2A_n}{A_1A_2A_3}.$$

But $A_2A_1A_4 = A_3A_1A_n$,

and $$\therefore \frac{A_2A_3A_n}{A_2A_3A_4} = \frac{A_1A_2A_4}{A_3A_2A_4} = \frac{A_1A_4}{A_3A_3} = 1 + 2\cos\frac{2\pi}{n}$$

is rational. Therefore $n = 2, 3, 4$, or 6.

This proof may be readily extended to the case of symmetry-axes of the second sort (axes of alternating symmetry). It assumes neither the rationality of the anharmonic ratio of four cozonal faces nor the fact that the symmetry-axis is parallel to a possible edge.

8. Suppose we have n points in a plane, and suppose every pair of points joined by a straight line. Suppose that one of these lines passes through r of the points $P_1, P_2, \ldots, P_{r-1}, P_r$. Now if one of these points (P_r say) is moved out of the line, the total number of lines is increased by $(r-1)$; for the r lines $P_1P_r, P_2P_r, \ldots, P_{r-1}P_r, P_1 \ldots P_{r-1}$ replace the

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single line $P_1 \dots I_r$. If now P_{r-1} is also moved out of the line, the total number of lines is increased by $(r-2)$ more lines, and so on. Suppose this process repeated until no line passes through more than two points; the number of lines is now $\frac{1}{2}n(n-1)$. Let u_r be the number of lines passing through r of the points and no more. Then we have

$$u_2+u_3+\dots+u_n = \tfrac{1}{2}n(n-1)-\sum_2^n\{(2+3+\dots+\overline{r-1})u_r\},$$

and therefore

$$n(n-1) = \sum_2^n r(r-1)u_r \quad \dots\dots \text{(i)}^1.$$

Again, in the above let v_r be the number of points at which r lines intersect, so that

$$\Sigma v = n \quad \dots\dots \text{(ii)}.$$

Then the total number of lines would be

$$v_1+2v_2+\dots+(n-1)v_{n-1},$$

if we reckoned each line through r points as equivalent to r lines. Therefore

$$v_1+2v_2+\dots+(n-1)v_{n-1} = 2u_2+3u_3+\dots+nu_n,$$

or

$$\sum_2^n\{(r-1)v_{r-1}-ru_r\} = 0. \quad \dots\dots \text{(iii)}.$$

Combining (i), (ii), and (iii) we have

$$n = \sum_2^n r(v_{r-1}-u_r) \quad \text{and} \quad n(n-2) = \sum_2^n r(ru_r-v_{r-1}).$$

Suppose we have n lines in a plane, and suppose that every pair of lines intersects in a point. Let U_r be the number of points lying on r of the lines, and V_r the number of lines on which r points lie. Then by reciprocation

$$n(n-1) = \sum_2^n r(r-1)\,U_r, \quad \sum_2^n\{(r-1)V_{r-1}-rU_r\} = 0, \text{ \&c.}$$

Using the gnomonic projection we deduce the following:—

If on a crystal with n faces (two parallel faces being considered equivalent to only a single face) there are u_r zones containing r faces and v_r faces lying in r zones ($\Sigma v = n$), then

$$n(n-1) = \sum_2^n r(r-1)u_r, \quad \sum_2^n\{(r-1)v_{r-1}-ru_r\} = 0,$$

$$\sum_2^n r(v_{r-1}-u_r), \quad \text{and} \quad n(n-2) = \sum_2^n r(ru_r-v_{r-1}).$$

[1] Another proof is given by E. von Fedorow, Abhandl. k. bayer. Akad. Wiss. München, Math.-phys. Cl., 1900, vol. xx, p. 496.

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Summary.

1. In the gnomonic projection of the poles of a crystal on any plane the projection of the pole of (hkl) is the point (hkl), and the projection of the zone $[HKL]$ is $Hx+Ky+Lz=0$, a suitable triangle of reference and suitable triliteral coordinates being taken.

2. By means of this theorem simple proofs of well-known crystallographic theorems may be obtained.

3. Some relations between the number (u_r) of zones of a crystal containing r faces, and the number of faces (v_r) lying in r zones may be found; e. g.,

$$n(n-1)=\sum_2^n r(r-1)u_r, \quad \sum_2^n\{(r-1)v_{r-1}-ru_r\}=0,$$

where $$\Sigma v_r = n.$$

University College,
Bangor, North Wales.

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On an Epidote from Inverness-shire[1].

By H. H. Thomas, M.A., F.G.S.

[Read January 31, 1905.]

THE mineral to be described was found by Mr. C. T. Clough, M.A., of the Geological Survey, near the junction of the two large streams in Coire Dhorrcail, near Barrisdale on the south side of Loch Hourn, Inverness-shire[2].

Mr. Clough furnishes me with the following description of the mode of occurrence of the mineral:—

'The crystals were obtained from a band, which, although its sides are not well exposed, seems to form a nearly horizontal vein-like mass. This band crosses both the bedding and the foliation planes of the muscovite-biotite-gneiss in which it occurs, and which occupies a large area near Barrisdale and Ladhar Bheinn[3].

'The vein from which the specimens were obtained is the only one of its kind which has been met with in the district; it consists essentially of an aggregate of crystals, varying considerably in size, of the mineral epidote, together with red garnet, and white quartz with thin films of a dark green actinolite.

'Some of these masses are as much as ten feet in width and contain large crystals of epidote embedded in white quartz. Most of the better shaped crystals occur in this way. Many of the crystals are traversed by cracks almost at right angles to their long axis; the various parts have suffered displacement, while the cracks are filled with granular quartz. The largest crystal noticed lay in an aggregate of smaller crystals of the same character, and measured six inches long by two broad.'

Well formed crystals were chosen for analysis, the mineral being crushed and subjected to the separating action of a heavy fluid in order to remove any impurities in the form of included minerals of lower specific gravity. The following are the results of the analysis, kindly made by Dr. W. Pollard, of the Geological Survey:—

[1] Communicated by permission of the Director of H.M. Geological Survey.

[2] Ordnance Survey of Scotland, one inch map, sheet 61.

[3] Summary of Progress for 1900 (Memoir Geological Survey), 1901, p. 10.

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Specific Gravity 3·37.

		Molecular ratios.	
SiO_2	39·02	0·646	6·00
TiO_2	trace		
Al_2O_3	28·64	0·2802	2·997
Fe_2O_3	6·81	0·0425	
FeO	0·34	0·0047	3·968
MnO	trace		
CaO	23·73	0·4238	
MgO	trace		
H_2O	1·76	0·0977	0·91
	100·30		

The above analysis gives the formula $Ca_4Al_6Si_6O_{25}H_2O$, in which the aluminium is partly replaced by ferric iron and the lime by ferrous oxide. Regarding the mineral as containing the group OH, we have

$$Ca_4Al_4(AlOH)_2(SiO_4)_6.$$

Dr. Pollard states that in the above analysis the ferrous oxide may be as much as 0·1 per cent. too low. As will be seen, the percentage of ferric oxide is very low for an epidote, and is only equalled by a few other epidotes, such as those from Huntington in Massachusetts[1], and the Zillerthal in the Tyrol[2].

The crystals are dark grey to greyish-brown in colour, but yield an almost white powder. They show a marked prismatic development, being elongated in the direction of the axis of symmetry, and attain in some instances, as has already been stated, a length of six inches. The faces of the orthodiagonal zone are by far the most strongly developed and form in most cases six- or four-sided prisms. Some of the smaller crystals are terminated, usually by simple forms.

The following are the faces which have been identified on the crystals measured:—

$a\{100\}$	$i\{\bar{1}02\}$
$c\{001\}$	$m\{110\}$
$r\{\bar{1}01\}$	$n\{\bar{1}11\}$
$f\{301\}$	$o\{011\}$

All these forms were noticed on one crystal, but the more common habit is represented by those crystals bounded by the faces *a c r n*.

[1] E. H. Forbes, Amer. Journ. Sci., 1896, ser. 4, vol. i, p. 26.

[2] H. Laspeyres, Zeits. Kryst. Min., 1879, vol. iii, p. 562.

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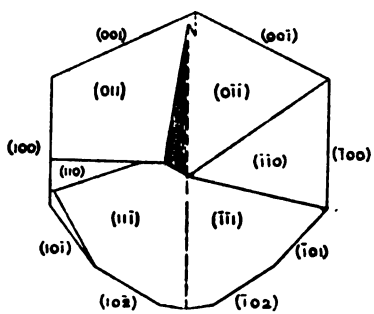
Below are given the chief measured angles as compared with those calculated from the axes of N. von Kokscharow, junr.[1], viz.:—

$a : b : c = 1{\cdot}57874 : 1 : 1{\cdot}80362$; $\beta = 64° 36' 50''$.

	Measured.	Calculated.
$ca = (001):(100)$ . . .	64° 37′	64° 36′ 50″
$am = (100):(110)$ . . .	54 48	54 59 54
$cn = (001):(\bar{1}11)$ . . .	75 3	75 11
$cr = (001):(\bar{1}01)$ . . .	63 49	63 42
$ci = (001):(\bar{1}02)$ . . .	34 38	34 21
$cf = (001):(\bar{3}01)$ . . .	98 16	98 37
$a'r = (\bar{1}00):(\bar{1}01)$ . . .	51 34	51 41
$a'n = (\bar{1}00):(\bar{1}11)$ . . .	69 5	69 2

All these angles were measured on crystals of small size and with bright faces, which gave for the most part good reflections. Only occasionally are the faces in the orthodiagonal zone striated parallel to the zone-axis. The larger crystals are much less perfectly developed, their faces are more irregular, and those of the orthodiagonal zone more deeply striated. The faces of $c\{001\}$ are usually bright and without irregularities.



Epidote from Inverness-shire. (Terminal faces of a small twinned crystal).

The mineral has a perfect cleavage parallel to c (001) and a less perfect one parallel to a (100).

Many of the crystals are simple twins with a twin-axis perpendicular to (100) and have (100) as the plane of composition. Polysynthetic twinning is by no means uncommon, following the same law.

A section cut parallel to the plane of symmetry gave the following extinctions for white light:—

Extinction measured to the trace of the good cleavage c (001), 23° 20′, and to the trace of the face a (100), approximately 1°.

The axis of least elasticity c was seen to make nearly a right angle with the face a (100),

therefore $a : c = 1°$ approximately.

[1] Verh. russ. min. Ges., 1880, ser. 2, vol. xv, p. 47. The position taken above is that used in Dana's 'System of Mineralogy,' 6th edit., 1892, p. 516.

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Owing to this small angle the polysynthetic character of the twinning is far from easy to recognize in sections cut at right angles to the twin-lamellae; but between crossed nicols sections, which are thin enough to show the bright colours of the lower orders, will appear banded, the lamellae say alternately blue and red.

The optical constants were determined from a single crystal, which showed twin-lamellae: fortunately the lamellae were thick enough to permit measurements being made on untwinned parts of the crystal.

For the determination of the refractive indices, two prisms were cut by Mr. John Rhodes. One with a face parallel to (010) and its refracting edge parallel to the **a**-axis, and the other with a face perpendicular to **c** and its refracting edge parallel to the axis of symmetry, or **b**, of the crystal. The first prism placed with the face (010) perpendicular to the incident light gave for sodium-light $\alpha = 1{\cdot}714$ and $\gamma = 1{\cdot}725$. By means of the second prism β for sodium-light was found to be $\beta = 1{\cdot}7196$.

The indices of refraction for yellow light are therefore:—

$$\alpha = 1{\cdot}714, \qquad \beta = 1{\cdot}7196, \qquad \gamma = 1{\cdot}725,$$

giving the relatively very low double refraction

$$\gamma - \alpha = 0{\cdot}011.$$

A plate cut perpendicular to **a** gave, in cassia oil[1], $2H_a = 98° 16'$ for sodium-light. This, with the above value for β, gives for the value in the crystal:—

$$2V_a = 89° 85'.$$

For thallium-light in cassia oil[2], $2H_a = 98° 18\frac{1}{2}'$; $2V_a$ therefore for thallium-light $= 90° 29'$.

The dispersion is slightly inclined; $v > \rho$. The optical character is negative for sodium-light, but positive for thallium-light.

The pleochroism is very distinct: for rays vibrating parallel to **b**, in sections 0·5 mm. thick, pale plum-colour; for those parallel to **a**, very pale plum-colour; and parallel to **c**, pale greenish-yellow, yellow predominating. The pleochroism scheme is therefore:—

$$\mathbf{b} > \mathbf{a} \gtrless \mathbf{c}.$$

A comparison of the epidote from Inverness-shire with those from Huntington, Zillerthal, and Val Maigels (Switzerland) brings out many points of interest, and shows a striking similarity in the chemical compositions. Below are given the analyses of the four epidotes in question.

[1] The refractive index of the oil for sodium-light = 1·60278 at 18°C.

[2] The refractive index of the oil for thallium-light = 1·61461 at 18°C.

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	Inverness-shire.	Huntington.	Zillerthal[1].	Val Maigels[2].
SiO_2	39·02	37·99	38·46	39·07
Al_2O_3	28·64	29·53	28·59	28·90
Fe_2O_3	6·81	5·67	5·76	7·43
FeO	0·84	0·53	0·53	—
MnO	trace	0·21	—	—
CaO	23·73	23·85	24·60	24·30
MgO	trace	—	—	0·10
H_2O	1·76	2·04	1·92	0·63
	100·30	99·82	99·86	100·43
Specific gravity	3·37	3·367	—	3·361

The pleochroism of the Inverness mineral is identical with that described by Forbes in the epidote from Huntington, and is very similar to that of the pale green crystals from the Zillerthal.

The mineral under investigation forms an interesting member of those epidotes with a low percentage of ferric iron, and falls naturally into the series. It has been recognized for some time that in the case of the epidotes the percentage of ferric iron has a direct influence on the refractive indices of the mineral, and on the other optical constants: namely, that with an increase in the percentage of Fe_2O_3 the values of the refractive indices and of the double refraction increase, while the dependent value of the angle between the optic axes measured over **a** decreases. A comparison of the Inverness epidote with those of Untersulzbachthal[3], Zillerthal[4], and Huntington[4], clearly illustrates the more or less gradual change in the optical constants (for sodium-light) as the percentage of ferric oxide decreases.

	Fe_2O_3.	α.	β.	γ.	$\gamma-\alpha$.	2V.
Untersulzbachthal	14·0	1·7305	1·7540	1·7677	0·0372	73° 39′
Zillerthal	6·97	1·720	1·7245	1·7344	0·0144	87 46
Inverness-shire	6·81	1·714	1·7196	1·725	0·011	89 35
Huntington	5·67	1·714	1·716	1·724	0·010	90 32

In the Huntington mineral the acute bisectrix is **c** and the optical character positive, so that measured over **a** the angle between the optic axes is 90° 32′.

[1] H. Laspeyres, loc. cit.

[2] G. vom Rath [Grey epidote from Val Maigels], Zeits. Deutsch. geol. Gesell., 1862, vol. xiv, p. 428. See also E. Weinschenk, 'Ueber Epidot und Zoisit,' Zeits. Kryst. Min., 1896, vol. xxvi, p. 176.

[3] C. Klein, Neues Jahrb. Min., 1874, p. 1.

[4] E. H. Forbes, loc. cit.

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The band from which the Inverness-shire specimens were obtained is on the Kneydart estate, the property of the late Mr. E. S. Bowlby; and Mr. Clough and myself wish to express our thanks to the factor, Mr. Stewart, for his kindness in ordering a blast to be put into the band referred to. My thanks are also due to my colleague Mr. O. T. Jones, who helped me considerably in my investigations.

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REVIEWS.

Manual of the Chemical Analysis of Rocks. By HENRY S. WASHINGTON, Ph.D. Pp. ix + 183. (New York: John Wiley & Sons; London: Chapman & Hall, Ltd., 1904. Price 8*s.* 6*d.* net.)

Of late years it is to the United States that we have learned to look for improved methods of manipulation and separation in the chemical analysis of inorganic bodies. In the case of rocks, the most recent and approved methods of analysis employed by the chemists of the United States Geological Survey have been made generally accessible by the recent publication of Hillebrand's admirable treatise. At first sight, therefore, there would appear to be little justification for this work of Dr. Washington's on precisely the same subject. The author, however, claims for his book that it has been written for that increasing class of petrologists and others who would like to make analyses of rocks, but who have had little or no experience in the subject, whereas Hillebrand's treatise is intended for the practised analyst. As one of the joint authors of that remarkable system of rock-classification, depending mainly on chemical composition, which has recently astonished the petrographical world, he is naturally anxious to render 'data in the way of rock analyses of superior quality more numerous.' In good hands the book, with its clear exposition of modern chemical methods, should certainly conduce to this desirable end, but, as it is avowedly intended to supply the student with such minutiae of detail that he may dispense with personal instruction, there is some cause to fear lest unskilled and careless workers be encouraged by its aid to perpetrate analyses of rocks and to publish their results. We are inclined to think that the chemist who is sufficiently advanced to produce trustworthy results will not require any more details than are given in Hillebrand's treatise. The book is nevertheless very welcome as a further means of making recent methods of rock analysis more widely known, for it is admirably written from the point of view of clearness and minuteness of detail. The student could have no better training in analytical methods than would be afforded by the guidance of this book in the analysis of an igneous rock, and it can be recommended to college professors who can spare little time for personal instruction to their students, since the directions given are very explicit and descend to such details as the sizes of beaker, filter-paper, and evaporating dish to be used in the various operations.

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A Handbook to a Collection of the Minerals of the British Islands, mostly selected from the Ludlam Collection, in the Museum of Practical Geology, Jermyn Street, London, S.W. By F. W. RUDLER, I.S.O. Pp. x + 241. (London: H.M. Stationery Office, 1905. Price 1*s.*)

An interval of almost half a century having elapsed since the publication, in 1858, of Greg and Lettsom's 'Manual of the Mineralogy of Great Britain and Ireland,' a new work on British minerals is specially welcome. The work is primarily intended as a handbook to a collection of minerals arranged by Mr. Rudler, since his retirement from his long held post of curator, in the Museum of Practical Geology. The book will have a permanent value as a treatise, for it is by no means a mere catalogue or descriptive list of all the specimens in the collection, nor is it, like Greg and Lettsom's manual, a descriptive mineralogy with complete lists of the localities of British minerals. Rather is it an extremely readable and interesting account of the mode of occurrence and history of British minerals, with special reference to their paragenetic relations, and their probable modes of origin, and with only brief reference to specific characters.

The mode of treatment is distinctly novel, the minerals being classified according to geographical distribution. Half the total number of minerals in the collection come from Cornwall and Devon, and about half the book is devoted to the consideration of these specimens. The remainder deals with minerals from the other mining districts of England, and includes a chapter on the minerals of the Neozoic strata, and short accounts of various mineral localities in Scotland, Ireland, and the Isle of Man. Under Cornwall and Devon the main headings are as follows:—cassiterite; minerals associated with cassiterite; copper sulphides and sulpho-ferrites; copper-bearing minerals of the gozzans; arsenates and phosphates from the copper-gozzans; ores of lead, zinc, antimony, &c.; sulphides and sulpho-salts; ores of iron, &c.; minerals of the rarer metals; the spars of the mineral veins; miscellaneous minerals.

The breadth and comprehensiveness of this work render it valuable not only to mineralogists, but also to geologists and to those interested in mining, while the numerous references to original papers furnish abundant evidence of the care and patience which have been bestowed upon its preparation.

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Minerals of Japan. By TSUNASHIRŌ WADA. Translated by TAKUDZI OGAWA. Pp. vii + 144, with 30 + 4 plates. (Tōkyō, 1904.)

This attractive-looking volume contains descriptions of 131 mineral species found in Japan, giving details of their mode of occurrence at the various localities, together with particulars relating to crystalline form and chemical composition. Much of the matter has been previously published in Japanese journals, but has not hitherto been accessible to European mineralogists; there are, for example, numerous chemical analyses of minerals which have not appeared before in a European language. The book, which is written in English, may be considered to be an extension of K. Jimbō's paper 'Notes on the minerals of Japan' (Journ. Sci. Coll. Univ. Tōkyō, 1899, vol. xi, pp. 213–281).

The excellent collotype plates, prepared from photographs of specimens in the author's collection, show very clearly the characteristic features of the minerals they represent. Special mention may be made of those representing the well-known Japanese minerals stibnite, rock-crystal in simple and twinned groups, topaz, and orthoclase. In addition to the plates, the text is well illustrated by outline figures of crystals.

Under the name naegite a new species is described from the alluvial tin washings at Naegi, near Takayama, in the province Mino. It is a silicate of uranium and thorium with some tantalum and niobium; the crystals appear to be tetragonal and isomorphous with zircon and thorite.

An examination of the mineral reinite, which has been described only from Japan, shows that it is not tungstate of iron crystallizing in the tetragonal system, but a pseudomorph of wolframite after scheelite, like the well-known pseudomorphs from Trumbull in Connecticut.

Since mineralogy was first taught in Japan by Karl Schenk, John Milne, and others, thirty years ago, considerable advances have been made in the science, and there are now several expert Japanese mineralogists, facts which the book before us amply testifies.

For information respecting Japanese localities of minerals the book will be found especially useful.

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NOTES.

The following deaths have to be recorded:—

Ronald William Henry Turnbull Hudson (1876–1904) met with a fatal accident on September 20 of last year while climbing in North Wales. He was the only son of Professor W. H. H. Hudson, of King's College, London, and after a distinguished mathematical career at Cambridge, where he was Senior Wrangler in 1898 and a Fellow of St. John's College, he was appointed Lecturer in Mathematics in the University of Liverpool. Although not a member of our society, he contributed to vol. xii of the magazine (with a supplementary note in vol. xiii) a mathematical paper having a bearing on crystallography.

Theodor Heinrich Behrens (1842–1905), since 1875 Professor of Microchemistry in the Polytechnic School at Delft in Holland. He was the recognized authority on microchemical methods of analysis, as applied, not only to minerals, but to a great variety of inorganic and organic substances, on which subject he published many memoirs and books; 'A manual of microchemical analysis' was published in English in 1894. In the same connexion he wrote on crystallites, and on the micro-structure of metals and of diamond; and was also the author of several papers on the petrography of the Dutch East Indies.

Joseph Patrick O'Reilly (1829–1905), for more than thirty years (1868–1899) Professor of Mining and Mineralogy in the Royal College of Science for Ireland, was born in the town of Monaghan on July 11, 1829, and died in Dublin on January 6, 1905. He was educated in Paris as a civil engineer, and for some years acted as engineer to mining companies in Spain, first at the zinc mines of Santander and afterwards at the sodium sulphate mines near Madrid. The results of the observations made by him in these districts were published, in conjunction with Dr. W. D. Sullivan, in 1863. He was the author of several papers on Irish minerals (one of which appeared in vol. xi of this magazine), but his work in other directions—in archaeology and in various branches of geology—showed that he had very wide interests. Professor O'Reilly was a most enthusiastic teacher and was much loved and respected by his pupils.

An interesting discovery of cassiterite has been made in eastern Ross-shire by the members of the Geological Survey. This mineral hitherto not been recorded from Scotland, and the discovery is

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of further interest on account of the unusual mode of occurrence of the mineral. The foliated granite-gneiss of Carn Chuinneag contains streaks and veins of granular magnetite, intermixed with which is cassiterite in amounts varying up to 17 per cent. This magnetite-cassiterite-rock has a foliated structure marked out by the interlamination of small quantities of quartz, felspars, micas, and rutile. A preliminary description of the occurrence is given in the 'Summary of Progress of the Geological Survey' for 1903 (1904, pp. 58, 81), and a special exhibit of specimens, maps, and photographs has been arranged in the Museum of Practical Geology.

An aegirite-riebeckite-gneiss has also been found in the granite-gneiss complex of the same district; this rare variety of hornblende-gneiss has not before been observed in the British Isles. Several other points of mineralogical interest might be mentioned from the volume quoted, for example, the discovery *in situ*, in a dyke-rock, of the withamite of Glencoe.

The enormous diamond found in the Premier mine in the Transvaal on January 25, 1905, has been described by Drs. F. H. Hatch and G. S. Corstorphine in the 'Geological Magazine' (April, 1905, pp. 170–172, plates vii and viii); their account is accompanied by process illustrations showing the stone in actual size from four different points of view. The stone weighs 3024¾ carats (=9600·5 grains or 1·37 lb. avoirdupois), and measures 4 by 2½ by 2 inches. It is a portion, probably not more than half of the original crystal, of a distorted octahedron, and is bounded by four natural octahedral faces and by four cleavage surfaces; the former are marked with striations parallel to the octahedral edges, and with triangular etched pits. The crystal is of remarkable purity and approximates in colour to the so-called blue-white.

The largest diamond previously known is the 'Excelsior,' a stone of 971¾ carats, found in 1893 in the Jagersfontein mine, Orange River Colony. The size of the newly found stone considerably exceeds that assumed for the originals of the famous Indian diamonds, the 'Great Mogul' and the 'Koh-i-noor.'

An account of the new Premier mine, which is situated about twenty miles WNW. of Pretoria, has recently been published in the Report for 1903 of the Geological Survey of the Transvaal (Pretoria, 1904, p. 43). It is of the same type as the Kimberley mines, but much larger in size, the pipe containing the 'blue ground' measuring over half a mile along the longer diameter of its oval-shaped cross-section, the area of which is

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estimated at 850,000 square yards. The pipe breaks through felsitic rocks which were earlier intruded in the quartzites of the Pretoria series.

A report on the progress of mineralogical chemistry during the year 1904 has been contributed by Dr. A. Hutchinson to the new volume of 'Annual Reports on the Progress of Chemistry' issued by the Chemical Society of London (1905, vol. i, pp. 222–244). Under the heading 'General and physical chemistry of minerals' are given reviews of the recent work of van't Hoff on oceanic salt deposits, of Judd and Cullis on dolomitization in coral reefs, and of Vogt on the crystallization of minerals in slags and molten mixtures of silicates. Brief descriptions are given of the new mineral species described in 1904, and some of the more important analyses of older minerals are quoted. A summary is given of recent work relating to the radio-activity of minerals, the artificial production of minerals, and several other points of interest. A list of meteorites analysed during the past year is also given.

A new mineralogical journal has appeared under the title 'Beiträge zur Mineralogie von Japan'; it is issued from Tōkyō by T. Wada. The first number, dated January, 1905, contains two papers by K. Jimbō, one on the crystalline form and etched figures of the fine crystals of danburite from Obira, and the other on the siliceous oolite of Tateyama; both papers are written in English and are illustrated with several figures. Short notes on Japanese minerals and on Chinese gem-stones are contributed by T. Wada, who writes in German.

A detailed and instructive account of the practical methods of drawing crystals is given by Professor S. L. Penfield in the American Journal of Science (1905, ser. 4, vol. xix, pp. 89–75). He has designed a special protractor for plotting crystallographic axes, and some special triangles for drawing lines parallel to these axes. The advantages of drawing an orthographic projection or plan in conjunction with a clinographic projection is specially insisted upon: this was first done by Koksharov in 1858 in his 'Materialen zur Mineralogie Russlands,' and has been used in this volume at p. 44.

The formula, Cu_5FeS_3, up to the present accepted for the common mineral bornite or erubescite is based on analyses made in 1839 on

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Cornish crystals. Professor B. J. Harrington (Amer. Journ. Sci., 1903, ser. 4, vol. xvi, pp. 151–154) shows that this formula needs revision; his analyses of massive bornite from several Canadian localities, and of crystallized material from Bristol, Connecticut, lead to the new formula Cu_5FeS_4. The old formula is readily explained by the fact that the Cornish crystals are always impure and usually contain a nucleus of chalcopyrite ($CuFeS_2$).

A natural occurrence of the artificial product known as carborundum, first prepared in 1893 by E. G. Acheson, and extensively used, on account of its extreme hardness, as an abrasive agent, has recently been noted by Professor H. Moissan (Compt. Rend. Acad. Sci. Paris, 1904, vol. cxxxix, p. 778; 1905, vol. cxl, p. 405). It was found by him in association with diamond in the meteoric iron of Cañon Diablo, Arizona, as small, green, hexagonal plates, identical in characters and composition with the artificial silicide of carbon (CSi). For this new meteoric mineral Dr. G. F. Kunz has proposed the name moissanite.

Fiedlerite, a mineral found in 1887 by G. vom Rath in the ancient lead slags of Laurion, Greece, where it is associated with the closely allied minerals laurionite ($PbCl_2.Pb(OH)_2$), paralaurionite, and penfieldite ($2PbCl_2.PbO$), has recently been analysed for the first time by A. de Schulten (Compt. Rend. Acad. Sci. Paris, 1905, vol. cxl, p. 315). His analysis leads to the formula $2PbCl_2.Pb(OH)_2$.

New names are still being given to imperfectly described minerals, but it is satisfactory to observe that many of these doubtful species, as well as some earlier ones, are being proved to have no existence. Such names need, therefore, only burden the lists of synonyms in the larger works of reference. Amongst identities recently proved, or suggested on good grounds, the following may be noted:—

Conchite = aragonite (R. Brauns, Centralblatt Min., 1901, p. 134; H. Vater, Zeits. Kryst. Min., 1901, vol. xxxv, p. 149).

Coolgardite = coloradoite + calaverite, &c. (L. J. Spencer, Min. Mag., 1903, vol. xiii, p. 268).

Dimorphite = orpiment (S. Stevanović, Zeits. Kryst. Min., 1904, vol. xxxix, p. 18).

Goldschmidtite = sylvanite (C. Palache, Amer. Journ. Sci., 1900, ser. 4, vol. x, p. 422).

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Hessenbergite = bertrandite (F. Grünling, Zeits. Kryst. Min., 1904, vol. xxxix, p. 386).

Huelvite = rhodochrosite + tephroite (Chemiker-Zeitung, 1903, Jahrg. xxvii, p. 15).

Hussakite = xenotime (E. Hussak and J. Reitinger, Zeits. Kryst. Min., 1903, vol. xxxvii, p. 563).

Hydrogiobertite = brucite + ? (L. Brugnatelli, Centralblatt Min., 1903, p. 148).

Kalgoorlite = petzite + coloradoite (L. J. Spencer, Min. Mag., 1903, vol. xiii, p. 268).

Kilbrickenite = geocronite (G. T. Prior, ibid., 1902, vol. xiii, p. 186).

Ktypeite = aragonite (H. Vater, Zeits. Kryst. Min., 1901, vol. xxxv, p. 149).

Lacroisite = rhodochrosite + rhodonite (Chemiker-Zeitung, 1903, Jahrg. xxvii, p. 15).

Lussatite = tridymite (F. Slavík, Centralblatt Min., 1901, p. 690).

Mamanite = polyhalite (J. H. van 't Hoff and G. L. Voerman, Sitz.-ber. Akad. Wiss. Berlin, 1904, p. 984).

Martinite = monetite (A. de Schulten, Bull. Soc. franç. Min., 1901, vol. xxiv, p. 325).

Metabrushite = brushite (A. de Schulten, ibid., 1903, vol. xxvi, p. 14).

Mooraboolite = natrolite (Min. Mag., 1903, vol. xiii, p. 373).

Palacheite = botryogen (A. S. Eakle, Amer. Journ. Sci., 1903, ser. 4, vol. xvi, p. 379).

Plusinglanz = argyrodite (A. Frenzel, Min. petr. Mitt. (Tschermak), 1900, vol. xix, p. 244).

Ramosite = basic volcanic scoria (L. McI. Luquer, Amer. Journ. Sci., 1904, ser. 4, vol. xvii, p. 93).

Reinite = wolframite pseudomorphous after scheelite (T. Wada, Minerals of Japan, Tōkyō, 1904, p. 76).

Simonyite = blödite (F. M. Jaeger, Min. petr. Mitt. (Tschermak), 1903, vol. xxii, p. 103).

Tamanite = anapaite (Zeits. Kryst. Min., 1903, vol. xxxvii, p. 267).

Torrensite = rhodochrosite + rhodonite (A. Lacroix, Bull. Soc. franç. Min., 1900, vol. xxiii, p. 254).

Viellaurite = rhodochrosite + tephroite (A. Lacroix, ibid., 1900, vol. xxiii, p. 253).

Wapplerite = rösslerite (A. de Schulten, ibid., 1903, vol. xxvi, p. 99).

Warrenite = jamesonite (L. J. Spencer, Nature, 1904, vol. lxix, p. 575).

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COMMUNICATIONS FROM THE OXFORD MINERALOGICAL LABORATORY. No. VII.

1. On the crystallization of sodium nitrate: by Professor H. A. Miers, D.Sc., F.R.S., and Jacques Chevalier.

2. On the crystallization of potash-alum: by Jacques Chevalier.

On the crystallization of sodium nitrate.

By PROFESSOR H. A. MIERS, D.Sc., F.R.S., and JACQUES CHEVALIER.

[Read January 23, 1906.]

EXPERIMENTS made by Professor Miers and Miss F. Isaac[1] have shown how, by measurements of the refractive index, it is possible to determine for a supersaturated solution the temperature at which it passes from the metastable condition, in which it can only crystallize by inoculation with a crystal of the salt (or of a substance isomorphous with it), to the labile condition, in which it may (and often does) crystallize spontaneously. In a diagram in which concentrations are taken as ordinates and temperatures as abscissae the solubility curve represents the limit between the unsaturated and the metastable state; and the limit between the metastable and the labile state is represented by a similar curve, to which they have given the name 'supersolubility curve'.

When a cooling solution is shaken, the passage to the labile state is

[1] Journ. Chemical Society, 1906, vol. lxxxix, pp. 413–454.

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generally marked by the appearance of a dense cloud of small crystals, but if there be crystals already present clouds may also appear in the metastable solution.

The present experiments were made with the object of ascertaining whether there is any difference in the mode of growth of crystals from a metastable and from a labile solution; what are the particular conditions which cause a labile solution to crystallize; at what parts of such a solution the first crystals appear and why; and how the clouds are produced.

The experiments are of three sorts:—

I. Test-tubes, immersed in a narrow glass trough filled with water at a known temperature, contain solution which is metastable at that temperature, and the growth and behaviour of an immersed crystal is watched by means of a microscope with its tube set horizontal, and the objective against the face of the trough. The tube may be plugged with cotton-wool, or the solution may be covered with a layer of oil at the same temperature, to prevent the access of crystalline germs from the air.

II. Drops of solution of such a strength as to be metastable at the temperature of the room are examined on a glass slide under the microscope until by evaporation, or by cooling, or both, they pass into the labile state. If it be desired to protect it from the air, the drop is enclosed by a cover-glass resting on a ring of Canada balsam, or of vaseline, surrounding the drop.

III. Solutions of known strength contained in sealed tubes are immersed in warm water, and are examined under the microscope while the water cools, in order to study their behaviour while at rest at known temperatures.

Such experiments might be carried on indefinitely, and are required for solutions of all sorts, since previous descriptions have not distinguished between the metastable and labile conditions.

The following experiments relate to sodium nitrate, because that substance has been most fully studied in the memoir referred to above, and because the problem is not complicated by the existence of two crystalline modifications or of salts containing different proportions of water.

I. *Experiments upon solutions in open tubes.*

One objection to the employment of a considerable volume of solution maintained at rest is the fact that, unless a long time be allowed for diffusion, different parts of the solution may be of quite different concentrations.

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If, for example, sodium nitrate be dissolved at the bottom of a test-tube, and care be taken not to shake the solution, the lower part of the liquid may be supersaturated while the upper part is unsaturated. The solution may be explored by an immersed crystal of the salt which can be watched under the microscope and seen to grow while in the lower part, but to dissolve while in the upper part of the tube; and sometimes quite a well-defined, oscillating meniscus may be found between the two. It is more than probable that one part of a solution may be in the metastable and another part in the labile state, or that there may be some streams of labile solution in the metastable liquid.

When crystals grow in an ordinary metastable solution they seem to originate either at the top or bottom of the liquid, or at both places; when the solution is uncovered, close examination shows that they probably originate at the surface and are carried to the bottom by their own weight or by the circulating currents. Their origin at the surface may be due to evaporation there, which reduces the solution locally to the labile state. If the liquid is exposed to the air, crystallization is also undoubtedly started in many instances by solid germs falling upon the surface. Attempts were made to prevent evaporation and access of germs by covering the liquid with a layer of oil at the same temperature; but even with this precaution crystals usually appear just below the oil before the solution as a whole passes into the labile state. Crystals so small as to be almost invisible may also be seen to rise in the ascending currents, and to remain at the surface until they have grown so large that they fall by their own weight. In a metastable solution, therefore, crystals always originate at the margin of the solution, and it is just possible that the first crystals may appear at the bottom as well as at the top of the solution.

The following is a striking difference between the two sorts of solution. If a crystal of sodium nitrate be immersed into the metastable solution, minute crystals at once form on it, all in parallel position; but if it be immersed into a labile solution the minute crystals which form upon it are in all sorts of positions and are not orientated as the parent crystal (the crystals also appear at the same time upon the sides of the tube and throughout the solution). This appears to indicate that in the labile solution a cloud of minute rhombohedra produced by the introduction of the large crystal attach themselves to it and then continue to grow rapidly, whereas in the metastable solution the centres of growth are only on the surface of the crystal. Precisely the same difference is noticed when a cleavage piece of the isomorphous calcite is employed.

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Again, if very minute crystals be quietly introduced into a metastable solution, a few other minute crystals appear in their neighbourhood while they are moving; but in a labile solution they produce a fine shower of crystals.

Clouds of small crystals are, however, not peculiar to labile solutions; they may also be produced, though in a much less degree, in metastable solutions by moving a crystal of sodium nitrate to and fro in the liquid. The moving crystal produces visible streams in its wake, and in these the small crystals make their appearance. When a metastable solution containing a few crystals is violently shaken, a cloud is formed; when a labile solution containing a few crystals is violently shaken, a much more dense cloud is formed and one which consists of much smaller crystals.

When crystals are introduced into the unsaturated solution, they are, of course, partly dissolved and become rounded; and they sometimes remain so when the solution passes into the metastable state, unless shaken. In one such experiment (49 per cent. solution) the rounded crystal was covered with small rhombohedra as soon as the liquid became metastable; but when moved suddenly (at 24°) to another part of the solution it shed a number of small crystals and ceased to grow; it only began to grow again (at its lower end) at 21°. Again, it is sometimes found that the edges and minute protuberances of a crystal introduced into the metastable solution remain unchanged, while the small crystals forming upon its surface in parallel positions are growing rapidly.

The following are the details of two experiments with introduced crystals:—

(1) A 47·6 per cent. solution (which becomes metastable at 24° C. and labile at 13½°), contained in a tube stopped with cotton-wool and immersed in water, was watched through the microscope. The temperature was lowered by the addition, from time to time, of cool water to that in the trough.

The temperature of the water being 24°, a sharp cleavage rhombohedron of sodium nitrate was suspended in the middle of the solution.

$t = 22°$: the crystal appears to be neither growing nor dissolving; a few crystals have formed on the side of the tube just above the edges of the meniscus.

$t = 21°$: a small crystal has formed and is growing upon the top of the immersed rhombohedron.

$t = 20{\cdot}6°$: the small crystal is growing regularly and is now accompanied by a second; the parent crystal may be growing slightly.

$t = 20{\cdot}5°$: fresh crystals are growing on the top of the parent crystal.

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$t = 20{\cdot}4°$: fresh crystals are growing on the surfaces of the parent crystal, all in parallel position, and especially along the inequalities of the faces.

$t = 17°$: a small crystal detached from the parent rises to the surface of the liquid; at 16° the streams proceeding from the parent crystal take some of the small crystals to the bottom.

$t = 14°$: the solution has become labile, a shower of small crystals is falling from the top of the solution, from the edges of the tube, and from the parent crystal.

$t = 10°$: the parent crystal is covered with small crystals.

(2) A fresh cleavage piece of sodium nitrate was introduced at 35° into a 50·65 per cent. solution (which becomes metastable at 38°, labile at 29°), and suspended just below the surface. It begins to be slightly dissolved, small particles separate from it and sink to the bottom, and are growing there while the temperature is 34°. The crystal being slightly moved produces visible streams in the liquid, and in these new crystals appear; the parent crystal continues to dissolve; the minute particles which fall from it only become visible a short distance below it; no cloud is produced by gentle shaking of the tube; at 32° the crystal was removed and found to have rounded edges and corners. No cloud was produced by moderate shaking till 28·5°, when the solution had become labile.

Several experiments were made in which a metastable solution, covered with oil, was stirred by means of a glass rod, which had been immersed in it for a long time while the solution was cooling from a high temperature: this usually produced a cloud, but it is impossible to prove that it may not be due to crystals already forming at the surface of the liquid and set in motion by the rod, or forming upon the rod just above the part immersed.

Scratching the side of the tube with a rod produces crystallization along the line of the scratch in a labile, and perhaps also in a metastable, solution; but if the tube be scratched before the cooling solution has attained the metastable state no crystals appear upon the scratch. Is it not possible that the effect is due to crystalline material which the rod has picked up on its entry through the surface? It may be mentioned here in this connexion that crystals do not seem to form in sealed tubes at the points where they have been rubbed by enclosed fragments of glass.

When a number of crystals appear in a metastable solution they seem to be propagated from one another by means of the concentration streams proceeding from each crystal, and it may be because these carry away

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the minute individuals which form upon the surface of the parent crystal. In a labile solution the streams are more active, and more general, and rapidly give rise to crystals of considerable size or to long needles.

Some attempts were made to introduce drops of labile liquid into a metastable solution, and in these experiments crystals seemed to be produced by the contact of the two liquids: but in all such experiments it is difficult to make sure that germs of solid crystals are not introduced at the same time, and it is possible that the crystallization is really due to these.

The whole process of crystallization and the formation of clouds may be beautifully shown by projection upon a screen, which renders it possible to watch the growth of individual crystals as they move through the liquid. By projection through crossed nicols the observations are made both more beautiful and more intelligible, owing to the polarization tints exhibited by the most minute crystals of sodium nitrate, which allow one to trace the increase in thickness of each rhombohedron as it rises or sinks through the liquid. A very common feature of this substance when growing in an agitated solution is the appearance, beside the ordinary rhombohedra, of fine hair-like crystals or rods. Projection upon the screen shows that these are only elongated rhombohedra growing rapidly in a vertical direction in the slender vertical streams of ascending or descending (perhaps labile) solution.

II. *Experiments with drops.*

When a crystal of sodium nitrate is introduced into a drop of the metastable solution it generally causes a few crystals to make their appearance at once in its immediate neighbourhood; the drops very often divide into two, and the portion which contains no crystals may remain without crystallizing until it reaches the labile state. When a crystal of sodium nitrate is introduced into a drop of the labile solution it causes the sudden appearance of crystals throughout the whole drop; if a portion separates, it also crystallizes at once.

In both cases a cleavage fragment of calcite produced exactly the same effect as a crystal of sodium nitrate.

The experiments are best performed by placing the drops on a slide close to the crystal, enclosing both with a ring of balsam or vaseline, and covering with a thin cover-glass. The drop is allowed to stand for a considerable time; the absence of crystals proves that it has not been contaminated by inoculation from the air, and the loose crystal may then be pushed in by means of a needle passed through the balsam.

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If a drop be left to itself without the introduction of a crystal it will not crystallize until it passes into the labile state, when a number of crystals make their appearance and continue to grow rapidly.

When a drop is free to evaporate the crystals appear first in a ring round the edge. No doubt the drop is locally reduced to the labile state at the edge.

A curious feature in the metastable drop into which a crystal has been introduced, and one which is not in accordance with the statements generally made, is that the small crystals produced in the immediate neighbourhood of the large parent crystal may proceed to grow rapidly while the parent crystal itself does not increase in size.

III. *Experiments with sealed tubes.*

The tubes employed were about 10 cm. in length and about 1·4 cm. in internal diameter, and were two-thirds filled with solutions of known strength.

When the tubes were placed in a horizontal position, the first minute crystals generally made their appearance, shortly after the labile condition was attained, at the bottom of the tube, and almost at the same time (but usually a little later) upon the surface of the liquid. The crystals which floated on the surface united themselves in a chain parallel to the length of the tube. When the tube is in a vertical position, isolated crystals can be seen beginning to form almost simultaneously at the top and bottom of the liquid, and others may be seen falling near the sides of the tube.

In general it appears that the first crystals which form upon the surface appear at or near the edges of the liquid, and that those which float gravitate to the lowest part of the meniscus, thus forming a chain when the tube is horizontal. It is possible that most of the crystals which appear at the bottom of the tube have fallen thither from the surface, but perhaps before they are large enough to be visible. It is, however, certain that some of those which grow on the surface have been taken there from below by ascending currents. The weaker the solution the larger and less numerous are the crystals which form; with stronger solutions they are smaller and more numerous, and form more rapidly.

Unless the salt be completely dissolved crystals will, of course, appear as soon as the solution falls to the saturation temperature. They sometimes appear although there is no visible solid in the solution; but this is always due to the fact that the tubes have not been heated for a sufficiently long time or have been inadequately shaken while heating.

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It requires prolonged heating and constant shaking to dissolve the last traces of salt.

On the other hand, if the tubes are kept at rest there is no reason why crystals should appear at the exact temperature at which the solution passes into the labile state. It is true that if the temperature be reduced very gradually the first crystals generally appear as soon as that state is attained if the tube be shaken, and give rise to a copious cloud. But if the tube be suddenly chilled it may be taken to a far lower temperature without crystallizing, and even then only a few crystals may appear, and may grow quietly unless the tube be shaken. Since in such experiments crystals do not usually appear unless either the tube contains some foreign substance, or has been warmed and shaken again while cooling, it is possible that the sudden chilling has only had the effect of reducing portions of the liquid to the labile state.

In general, if a solution be kept quiet, it is very difficult to distinguish between the metastable and labile states. For isolated crystals, which may appear spontaneously or have been introduced, may continue to grow independently in a uniform manner in either solution. It is only when the tube is shaken that a distinction can be observed. If the tube contains no crystals a cloud appears in a labile, but not in a metastable, solution. In a labile solution it is possible, by slightly moving a tube containing a crystal, to produce a fine cloud at a distance from the crystal: with a metastable solution this is not possible. If there be crystals present, the cloud produced by shaking a metastable solution is quite different in character from that of a labile solution. The former is thin and consists of comparatively few nuclei; the latter is dense. We distinguish them as a 'metastable cloud' and a 'labile cloud'.

In the production of these clouds the initial temperature seems to be an important factor: if the solution be reduced by sudden cooling from the metastable to the labile temperature, and then shaken, a dense labile cloud is produced: but if it be reduced to the labile temperature by sudden cooling from a higher temperature, and then shaken, a metastable cloud is produced. In these experiments, again, it is possible that though the solution is, in part at least, reduced to the labile temperature, it is not completely reduced to the labile state; for the process of crystallization resembles that in a metastable solution into which a few crystals have been introduced.

A number of experiments were made with tubes containing other substances in addition to the solution of sodium nitrate. In all these it

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was found that a piece of calcite (either a cleavage fragment or a crystal) produces exactly the same effect as a crystal of sodium nitrate. It is, of course, impossible to introduce a crystal of sodium nitrate in the same way as one can an insoluble substance like calcite: but with care it is possible to leave a small crystal adhering to the top of the tube while the rest is completely dissolved in the lower part. As soon as the solution passes into the metastable state crystals begin to grow in parallel position on the calcite: if other substances appear to relieve the supersaturation like calcite, it is only because the sodium nitrate has not been completely dissolved, and their presence renders solution a little more difficult. If the solution has been complete, calcite is the only substance which has this power, as we have proved by comparative experiments on tubes of the same solution containing different mineral substances, examined side by side. Calcite appears to act even more energetically than sodium nitrate itself: for example, with a tube of 50 per cent. solution containing a piece of calcite in the liquid and crystals of sodium nitrate out of it, crystals began to appear on and near the calcite at 35°; when the liquid was brought into contact with the sodium nitrate the crystals produced in their neighbourhood did not grow so rapidly, and were not so numerous as those close to the calcite.

The crystals which form in a sealed tube at rest almost invariably exhibit a minute triangular speck on one face; and when crystals growing on the surface of the solution are watched from the time of their first appearance, this spot is seen to occupy the position of the original nucleus; it may be a cavity (hopper-structure) on the upper surface of the crystal, produced by the presence of solution round the crystal and absence of solution above it, as generally happens with floating crystals. This suggests that all these crystals have originated in the surface of the liquid.

IV. *General conclusions.*

We would not venture to draw any general conclusions from the preceding rather fragmentary experiments, were it not that the experiments upon sodium nitrate are, in general, confirmed by those upon other substances, although we have in the present communication confined ourselves to sodium nitrate.

The experiments show that the process of crystallization enables us to distinguish between the metastable and labile states, and so confirm the distinction which has been already established by means of the refractive index.

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An aqueous solution, either by cooling without serious change of concentration, or by evaporation of the solvent without serious change of temperature, or by both, becomes supersaturated and passes first into the metastable state (in which it will only crystallize by inoculation with a crystal of the solute or of an isomorphous substance) and then quite suddenly into the labile state (in which it may crystallize spontaneously). Spontaneous crystallization in the latter is generally induced by shaking or by friction, but in any case it is started by introduction of a crystal of the solute or of an isomorphous substance; whereas the introduction of such a crystal into the metastable solution only produces a few crystals in its immediate neighbourhood.

In a metastable solution centres of growth are only on the surface of a crystal already present, in a labile solution they may be anywhere.

When a labile solution containing a crystal is shaken, a dense cloud of new crystals is produced, both by the contact of the crystal with fresh portions of the solution, and by the creation of fresh centres of growth at a distance from itself owing to the mere motion of the liquid.

The cloud which is produced when a metastable solution containing a crystal is shaken is not so easy to explain: but it is certain that a number of minute crystals grow on the surface of the parent crystal as soon as it is introduced: it is probable, therefore, that many of these get loose and become new centres of growth when the crystal is moved through the liquid; and even when the parent crystal is still, they may be swept away from it by the concentration streams.

We were at first inclined to think that a crystal can only grow in contact with a labile solution; that when a crystal is growing in a metastable solution this is only due to the liquid in contact with it being so concentrated as to be really labile; and that therefore the cloud produced by moving a crystal in a metastable solution is due to droplets of this enveloping halo of labile liquid getting loose, and becoming new centres of growth. Experiments made by one of us[1] upon the strength of the solution in contact with a growing crystal of sodium nitrate have, however, shown that this liquid is not labile but metastable. We are therefore led to the conclusion that the cloud is produced by the liberation, not of liquid, but of solid particles from the parent crystal: and that these solid particles exist has been proved above by direct observations.

The fact that the liquid in contact with the growing crystal is not labile, but metastable, explains another curious feature of the experiments. It seems strange that in a labile solution a crystal which has made its

[1] H. A. Miers, Phil. Trans., 1903, Ser. A, vol. ccii, p. 515.

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appearance should continue to grow quietly, and that crystallization should not spread through the whole liquid which is *ex hypothesi* ripe for it. But this is prevented by the halo of metastable solution which surrounds the growing crystal and protects the labile solution from contact with the solid. The experiments seem to indicate that this is only true of a crystal which has appeared spontaneously in the solution, whereas a crystal *introduced* into a fully labile liquid starts crystallization throughout the liquid.

If this be true, then a crystal growing in a labile solution is surrounded by a halo of liquid less concentrated than the main mass; but a crystal growing in a weakly supersaturated metastable solution may be surrounded by a halo of more concentrated solution.

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On the crystallization of potash-alum.

By Jacques Chevalier.

[Communicated by Professor Miers, and read November 14, 1905.]

As has been mentioned in the preceding communication, a supersaturated solution, which is cooling or evaporating, passes successively into the metastable condition, in which an introduced crystal can grow in it, and then into the labile condition, in which it may crystallize spontaneously. The transition is indicated by a sudden change in the refractive index of the solution. It seems possible that in these two distinct states of the solution there may be a difference in the mode of growth of the crystals. In the following experiments an attempt was made to find evidence of such a difference by the examination of thin drops of solution crystallizing under the microscope: and potash-alum was found to be a convenient substance for the purpose.

Preliminary experiments with drops of supersaturated solution of potash-alum showed that when a crystal of the same salt was introduced at the edge it became immediately surrounded by small crystals apparently detached from it, and that, after a few minutes, the remainder of the drop crystallized suddenly in the form of a very regular geometrical pattern consisting of a rectangular network of isotropic fibres. This change suggested that the two modifications might possibly correspond to the two states; further experiments were therefore made with solutions of known strength.

The solutions used generally were 19·75 per cent. solution (which passes into the metastable state at 40° C., and into the labile state between 25° and 28°); and 18 per cent. solution (which passes into the metastable state at 37°, and into the labile state between 24° and 21°).[1] After the salt had been completely dissolved, the solutions were kept in test-tubes plugged with cotton-wool, at a constant temperature of about 35° or 30° respectively. Drops were taken from the solution with a glass rod, and deposited without a cover-glass on a slide warmed to the temperature of the solution; both rod and slide having been sterilized by passing them through the flame of a Bunsen-burner. The solution chosen was such that the drop might be just metastable for the temperature of the room,

[1] These limits were determined by experiments with solutions contained in sealed tubes, being the temperatures at which such solutions crystallize when shaken.

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and it was watched under the microscope while becoming labile by evaporation.

It was soon noticed that three sorts of crystals may be observed even in the same drop: namely ordinary octahedra, the rectangular network mentioned above, and birefringent spherulites. I will denote these by the letters *O* (octahedra), *R* (rectangular network), and *S* (spherulites). An octahedron, for instance, may be growing in one part of the drop, while spherulites appear at the edges; again a drop inoculated with *O* may deposit in places octahedra, whereas in other places, where the drop is thinner and spherulites have begun to appear, it deposits the network, on which appear octahedral terminations. Closer examination showed that the coexistence of the three forms in the same drop is actually due to differences of concentration between the different parts of the drop, especially between the middle part and the edges.

The drops generally yield in succession spherulites or octahedra, and later the rectangular network.

Spontaneous crystallization in the metastable and labile states.

(1) *The Spherulites.*—If the drop be left to itself, the spherulites (*S*) ordinarily grow first, except in the case of a very small drop, which is quickly converted into an amorphous mass with a stippled surface.

In rather large drops a number of crystalline aggregates, identical with the 'cauliflower crystals' of Loewel[1], from which sheaves of birefringent material radiate, are visible after a time varying generally from four to ten minutes: they appear all round the edges, especially after the drop, owing to evaporation, has begun to contract and to present uneven edges. They spread little by little from the edge into the whole drop, which becomes finally converted into spherulites and birefringent plates, with some of the amorphous material between them. All spherulites present the typical cruciform extinction, and some of them a spiral structure. In drops placed on very hot slides nothing appears but amorphous wrinkled material on the edges and small spherulites nearer the centre.

The spontaneous appearance of the spherulitic material may be considered as an indication of the passage into the labile state. For if a drop taken from a solution, which is about to become labile at the temperature of the room, be placed under a cover-glass resting on a ring of vaseline so as to prevent evaporation, crystals do not appear until the temperature is reduced, when the drop crystallizes entirely as spherulitic material. The same result is obtained, provided sufficient care be taken,

[1] Loewel, Annales de Chimie et de Physique, 1855, vol. xliii, p. 416.

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when the temperature of the room is below the labile point: as soon as the drop has cooled to the temperature of the room, spherulites appear throughout the whole drop. Cooling, therefore, produces the same effect as evaporation upon a drop which is just about to become labile, and the appearance of the spherulitic material marks the change.

(2) *The Octahedra.*—Octahedra, in general, only grow if they have been introduced into the drop. It is true that cold drops often yield octahedra at once, but these do not necessarily, as is the case with *S*, appear on the edges, where the solution is presumably stronger: they may appear anywhere in it, and generally upon hairs or dust. They have either been introduced with the dust of the air or originate from crystalline germs transferred with the drop from the test-tube. A metastable drop, when free from germs and kept covered or sealed, never deposits octahedra; nor does it when it is cooled to the labile temperature, in which case spherulites only form. But if the drop originally contains one or several crystalline germs of alum, regular octahedra form little by little, and may continue to grow so rapidly that the drop never passes into the labile state in which *S* and *R* may appear.

(3) *The Rectangular Network.*—When the growth of octahedra in a metastable drop has not been very rapid or widely spread, the isotropic rectangular network may appear in parts of the solution which have remained uncrystallized. As a rule this rectangular network only appears after *S* has formed. It spreads round the edges, and, in the case of a thin drop, all over the drop. After a while it becomes white and opaque, and, at the same time, separates from the spherulites and from introduced crystals.

The rectangular network is produced by the introduction of a fragment or germ of octahedral alum into a drop from which *S* is growing. It generally makes its appearance in drops which already contain *S*, but some experiments indicate that it may appear spontaneously in drops which contain no crystals.

The supersaturated drops therefore behave differently according as they are in the first state, in which no crystals grow spontaneously, or in the second state in which *S* may, and does, appear by itself. The first is the metastable, and the second the labile, condition with reference to octahedral alum.

Effect of stirring.

(1) Stirring of drops free from crystals:—

(*a*) *Metastable.*—Stirring with a clean rod metastable drops in which there is nothing visible, produces no effect.

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(*b*) *Labile.*—Stirring a drop in which a few spherulites are growing makes a number of minute spherulites appear. Sometimes the middle part of the drop separates, and becomes suddenly converted into the amorphous stippled material.

(2) Stirring of drops in which octahedra are growing:—

(*a*) *Metastable.*—In a large drop in which some introduced octahedra are growing the crystals, when moved with a clean rod, leave a train behind them; the germs thus formed continue to grow individually, with a cluster of minute particles close to them. Stirring at a distance from the crystals, however, produces no effect.

(*b*) A few minutes later, when *S* begins to appear at the edges, the same drop is stirred again: a cloud of particles is suddenly produced throughout the drop, and chains of minute octahedra extend in a remote portion of the drop which had been clear; fresh crystals also appear in the solution further on in the direction along which the crystals grow.

(*c*) *Labile.*—An octahedron which is growing in the middle of the drop being moved rapidly with a clean rod while *S* is appearing on the edge itself makes the network *R* to spread round the edge.

Inoculation of metastable and labile drops with the different modifications.

(1) *Metastable drops.*—If a drop in which nothing is visible be inoculated with *S*, the spherulite, when placed in the middle of the drop where the solution is more dilute, generally disappears. When placed at the edges it yields minute octahedra.

When a metastable drop is inoculated with *O* or *R*, octahedra are produced: they spread at once from the fragment of *R* or from the introduced *O* in the part of the drop which is in contact with it.

(2) *Labile drops.*—In a drop in which *S* is just starting to form, a small spherulite being introduced makes the amorphous material appear round it; new spherulites are also formed. Very often some long sheaves of isotropic material spread from them, which, after a while give rise to the rectangular network.

If the drop be inoculated with *O* or *R*, or even, as it seems, with a drop of strongly supersaturated solution of potash-alum, the geometrical network at once spreads over the whole drop.

(3) It sometimes happened that alum crystals, either *O* or *R*, introduced into a drop where nothing had yet appeared, made the drop

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crystallize in the network. As I supposed this to be due to the fact that the drop was just passing into the labile state, the experiment was repeated with drops which were certainly metastable. In these, octahedra alone appeared, never the rectangular network.

The different modifications and their effect upon each other.

It is probable that we have to do with two varieties of potash-alum: *S* and the birefringent plates being a less hydrated variety; whereas *R* and *O* are the ordinary hydrated alum, which has crystallized in different forms owing to the different conditions of the solutions. The next step is to examine more closely the different modifications and their relation to each other.

A curious effect is the frequent solution of *S* by *O*. Thus in a drop in which a single large octahedron was growing at one side of the drop, while *S* appeared at the other side, it was noticed that, as the alum crystal advanced near to a group of birefringent plates, the liquid surrounding the alum dissolved away the plates. As soon as the octahedron touched the birefringent sheaf, the cubic network started from the point of contact and ran round the whole drop, becoming lined on the inside with octahedral terminations.

This shows that the zone of solution in contact with an octahedron in a labile drop (where *S* is growing) is metastable (since it dissolves *S*). An alum crystal growing in a metastable solution is surrounded, as Professor Miers has previously proved, by an envelope of liquid which is more strongly supersaturated, but is still metastable for alum. When the solution passes into the labile condition, so that the sphero-crystals begin to appear, the alum crystals, instead of producing the network characteristic of that stage of supersaturation, continue to grow unchanged: this indicates that they maintain around them a zone of metastable liquid, which isolates them from the remainder of the drop, and prevents them from starting the network.

This very interesting fact and the conclusions it suggests were confirmed by many experiments. Thus:—

(1) An octahedron which has been growing in a drop from the beginning, and did not start the network even after a number of spherulites had appeared, being taken out and immediately reintroduced into the drop, or rapidly moved in it, makes it at once crystallize in the network.

(2) A fragment of octahedral alum being introduced into a labile

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drop in which an octahedron is growing and which contains a foreign substance (e.g. corundum), causes the network to spread throughout the drop: it surrounds the other substance completely, but it stops before reaching the octahedron, delineating quite clearly in that way the zone of metastable solution in which the network cannot grow.

(3) The network, at the place where it stops round *O*, grows little by little in octahedra, characteristic of a metastable solution, just as it ordinarily does towards the centre of the drop where the solution is more dilute than at the margin.

(4) When a drop, in which *O* has been growing, suddenly develops the network, it is probably because the zone of metastable solution round *O* has broken at some point, so as to allow a portion of the octahedron to come in contact with the labile solution. This happened, for instance, after the octahedron had touched the birefringent plates, or when a sudden movement had been caused in the liquid, by introduction of a foreign substance, or by stirring, &c. Thus, beautiful rectangular lines may spread from an extremity of *O*, which becomes at once enveloped by them; but the network stops before it reaches the other portions of the same octahedron.

The spherulitic material *S* is certainly more soluble than the octahedra, since it is dissolved by the solution in which *O* is growing. And yet it is a less hydrated alum. When breathed on or simply exposed to moist air the spherulites become uniformly isotropic, and shortly afterwards begin to crack and become white and opaque. This change of birefringent into isotropic material is due to the conversion of *S* into *O*, as shown by various experiments: thus a hot solution on a hot slide solidified suddenly as an amorphous mass in which spherulites rapidly developed; addition of water produced a fine crystallization of *O*: and as it spread over the mass the network suddenly appeared.

Again, a drop *B* was placed beside a drop *A*, three minutes after *A* had been placed on the slide. The drop *A* crystallized in spherulites all round the edges, with amorphous stippled material in the middle. About the same time spherulites appeared in the small channel of liquid joining *A* and *B*: when they reached *B* they were suddenly transformed into octahedra, and the network immediately spread in *B* at the edges, with large octahedral terminations growing towards the inner part of the drop. This indicates that the spherulites may become transformed into octahedral alum by contact with a more dilute solution and may so inoculate it.

The change of birefringent *S* into isotropic *O* was watched by immersing

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a fragment of a well-formed spherulite in a small drop of water: it at once became isotropic and began recrystallizing on its surface in the octahedral modification, the centre becoming more and more brown and opaque; the whole ultimately became converted into octahedra, but some of these were fringed with birefringent threads as there was probably not enough water to transform it entirely into ordinary alum.

The material of the rectangular network *R* is undoubtedly cubic: it presents a very perfect cubic structure. When a particle of it is introduced into a labile drop, a uniform network spreads over the whole drop, and the fibres remain constant in direction. The crystals when examined between crossed nicols, always proved to be isotropic. *R* becomes white and opaque after a time, owing to the development of cracks proceeding both from the centre and from the edges: this generally happens when the network presents radial groups of rectangular fibres, differently inclined to each other; when it is uniform it does not always break up. The opacity (as also that of *S*) disappears when *R* is immersed in oil, showing that it is only due to cracks.

R is, therefore, ordinary alum which is in a state of strain, owing to its rapid crystallization. The whole difference between *R* and *O* is explained by their mode of crystallization: octahedra only form in a metastable solution; they cannot appear if not introduced, and only grow individually by separation of crystals from an already formed crystal. *R* only starts in a labile drop: it is a parallel growth of *O* extended along the axes of a cube, and in the metastable parts of the solution it terminates in octahedra.

Evidences of different behaviour in the metastable and labile conditions.

From these experiments it appears that a supersaturated drop of potash-alum, which is either cooling or evaporating, or both, passes successively into two different states: one in which no cubic crystals appear unless introduced; but an introduced crystal grows and reproduces itself, either in its immediate neighbourhood, or, when stirred, in all parts of the drop. This is the metastable state. The crystalline form proper to this state is the common octahedral alum: *R* or *S* if introduced yield *O*. The second state is one in which birefringent sphero-crystals may, and do, form spontaneously; or an introduced particle of octahedral alum sets up at once, throughout the whole drop, a very perfect microcrystalline structure, in which the fibres are parallel to the axes of the cube, and the crystals are isotropic.

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Now these two events, the spontaneous production of *S*, and the appearance (whether spontaneous or induced) of the rectangular network *R*, always occur in the same stage: *R* can only be started when *S* has already appeared, or when it is about to appear, and it can in fact be produced by inoculation with *S*. On the other hand, birefringent crystals only grow in a state of solution for which *R* is the characteristic crystalline growth. No local formation of *O* is possible in a solution from which *S* is growing: when *O* is found in such a drop it is because it has grown unchanged from the precedent metastable state, preserving round itself a zone of that solution; *O*, if introduced into the drop, yields the rectangular network.

Therefore *S* and *R* may be taken as indicative of the labile state of the solution: they present the two distinctive marks of a labile solution, namely, spontaneous crystallization, and a diffused growth indicating a sudden change throughout the whole liquid.

The only difficulty is that the passage into the labile state is not marked by the spontaneous appearance of the substance (ordinary alum) with regard to which the solution becomes labile; it is always the birefringent variety, more soluble and less hydrated, which appears spontaneously in the labile solution. This may be explained by supposing, either that the solution becomes labile for the one just before it becomes labile for the other, or that the birefringent modification, although it is less hydrated, crystallizes more easily from a solution which is labile for both, than does the ordinary hydrated and isotropic modification.

It is interesting to compare the behaviour, in a test-tube, of the solution from which the drop has been taken, with the behaviour of the drop itself. The introduction and moving of an alum crystal in a tube of labile solution produces the kind of cloud that has been described in reference to sodium nitrate, and which we called a 'labile cloud'; in the drop it produces *R*; so that the labile cloud in a large volume of liquid exactly corresponds to the network in a thin layer of the same liquid.

The rectangular network is not, therefore, an abnormal growth, due to the physical condition of drops. No doubt its dendritic aspect, and the extreme rapidity of its propagation in certain directions may be due to the thinness of the drop: but it corresponds to the labile cloud in a larger volume of solution, and both are fully accounted for by the greater concentration of the liquid. The geometrical arrangement of *R* is a result of the crystalline structure of the cubic system. It is just possible (see experiments quoted above, p. 140) that the solution, when

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passing into the labile state, may be arranging itself, before the appearance of the network, along certain directions related to the crystalline structure of the substance dissolved.

Note on inoculation with other materials.

This led me to think that, besides potash-alum and the substances isomorphous with it, other mineral substances might possibly have an influence on the crystallization of a labile drop of potash-alum solution. A great many experiments were made in order to ascertain this influence. The general results may be recorded here, although they require further confirmation before any decisive conclusion can be drawn from them.

Spinel, galena, and fluor, introduced into a drop of labile 19·75 per cent. solution produced the rectangular network, and the fibres of the latter appear sometimes to be parallel to the axes of the introduced crystal. Minerals of lower symmetry, such as blende, pyrites, and cuprite, do not cause the network to appear. With a weaker solution or a lower temperature, the network may be produced by inoculation with all these minerals as also with garnet, leucite, corundum, bismuth, quartz, topaz, and gypsum, but not with mica or glass.

But in all the experiments galena operated far more readily than any of the other substances in producing the rectangular network in a labile drop, and succeeded where they failed.

In metastable drops, on the other hand, topaz and (even more conspicuously) thorianite, which have little effect on labile drops, cause the appearance of octahedra far more readily than the other minerals, even than galena, which in fact has no such action in a metastable drop.

Comparative experiments suggest that in the labile solution the action of the introduced crystal may depend mainly upon its symmetry, whereas in the metastable solution it may depend more upon other factors.

The experiments described in this paper were carried out in the Mineralogical Laboratory of the Oxford University Museum, at the suggestion of Professor Miers.

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The identity of the Amiantos or Karystian stone of the Ancients with Chrysotile.

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[Read June 14, 1905.]

FLEXIBLE mineral fibres appear to have been well known to the Greeks, who spun them into thread, which they wove into cloth or employed as wicks for lamps.

Pausanias, who lived in the second century of the present era, tells us that Kallimachos made for the statue of Minerva in the Acropolis at Athens a lamp of gold, the wick of which was of 'karpasian flax', which he states is the only flax inconsumable by fire.[1] Some have interpreted the words 'karpasian flax'—*λίνον καρπάσιον*—as meaning mineral flax from the Karpasos, the north-eastern promontory of Cyprus, but apart from the fact that there is no record of the occurrence of asbestiform minerals in that locality, it seems clear that the word *καρπάσιος* is derived from *κάρπασος* (feminine in the singular, but neuter in the plural *κάρπασα* or *κάρβασα*), which properly signifies cotton, being identical with the Sanskrit *kârpâsâ*, though it has been used for a fine variety of flax produced in Spain, as well as for other European plants. The mineral used in the sacred lamp was therefore presumably similar to cotton in softness and fineness. Nothing is said as to the locality from which it was obtained, but it was probably the produce of the quarries near Karystos, at the southern end of Euboea, which appear to have been the best known source of flexible mineral fibres in ancient times. They were in fact generally referred to as the Karystian stone (*ὁ Καρύστιος λίθος*).

[1] *Καὶ οἱ λίνου καρπασίου θρυαλλὶς ἔνεστιν, ὃ δὴ πυρὶ λίνων μόνον οὐκ ἔστιν ἁλώσιμον.* Pausanias, *Ἑλλάδος Περιήγησις, Ἀττικά*, chap. 26.

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Strabo, who wrote in the beginning of the first century, tells us that in Karystos occurs the stone which is carded and woven to form handkerchiefs[1]; and, like almost all ancient writers who refer to asbestos, he states that the fabrics formed of it were cleansed by casting them into the fire.

Solinus states that Karystos possesses, among other marvels, cotton which stands fire.[2]

The quarries near Karystos appear, however, to have become exhausted, for we read in Plutarch (50–139 A.D.) that, at the time when he wrote, it was not long since the quarry had ceased to yield soft tissues (*μηρύματα*) of stone which could be drawn out into the form of thread[3]; and after referring to their use in making handkerchiefs and nets, he states 'that they, the *μηρύματα*, have now disappeared and scarcely more than fibres or slender hairs are embedded in the rocks of the quarries.'[4]

The rocks round the modern town of Karystos consist of crystalline schists, while one and a half hours to the east are two exposures of serpentine[5], so it is not improbable that the asbestos was really chrysotile, the fibrous variety of serpentine.

The only other locality, from which mineral textile fibres are said to have been obtained in ancient times, is the island of Cyprus. One of the earliest writers on minerals was Sotakos (Σώτακος or Τάκος), who is several times referred to by Pliny. In an extract from his book Περὶ λίθων, which has been preserved to us by Apollonius Alexandrinus Minor, he states that 'the stone called the Karystian has woolly and skin-like growths from which handkerchiefs are spun and woven, and they also twist wicks from it.'[6] After describing its incombustible character, he

[1] Ἐν δὲ τῇ Καρύστῳ καὶ ἡ λίθος φύεται ἡ ξαινομένη καὶ ὑφαινομένη, ὥστε τὰ ὑφάσματα (v.l. ὕφη) χειρόμακτρα γίγνεσθαι. Strabo, Γεωγραφικῶν, Bk. x, chap. 1, par. 6.

[2] 'Carystos aquas calentes habet (Ellopias vocant), et Carystias aves quae flammas impune involant, carbasa etiam quae inter ignes valent.' An editor has unnecessarily altered 'valent' to 'lavant'. C. Julius Solinus, 'Polyhistor,' chap. 11, par. 15.

[3] Καὶ μετάλλων ἴσμεν ἐξαμαυρώσεις γεγονέναι καινὰς ὡς . . . τῆς τ' ἐν Καρύστῳ πέτρας, χρόνος οὐ πολὺς ἀφ' οὗ πέπονται μηρύματα λίθων μαλακὰ νηματώδη συνεκφέρουσα. Plutarch, Τὰ Ἠθικά, Περὶ τῶν ἐκλελοιπότων χρηστηρίων, Bk. ii, 434 *a* (edition 1796, vol. iv, p. 772).

[4] Νῦν δὲ ἠφάνισται, καὶ μόλις οἷον ἶνες, ἢ τρίχες ἁραιαὶ διατρέχουσιν ἐν τοῖς μετάλλοις (loc. cit.). Literally, 'run through in the quarries.'

[5] Friedrich Teller, 'Der geologische Bau der Insel Euboea.' Denkschr. k. Akad. Wissensch. Wien, Math.-Naturw. Classe, 1880, vol. xl, p. 153.

[6] Ὁ Καρύστιος λεγόμενος λίθος ἐπιφύσεις ἔχει ἐριώδεις καὶ χροώδεις, ἐξ οὗ νήθεται καὶ ὑφαίνεται χειρεκμαγεῖα, στρέφουσι δὲ ἐξ αὐτοῦ καὶ ἐλλύχνια. Apollonius Alexandrinus Minor or Dyskolos, Περὶ κατεψευσμένης ἱστορίας, chap. 36. The word χροώδεις does

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continues: 'This stone is produced in Karystos, from which it took its name, and there is much in Cyprus on the left hand of those travelling down from Gerandros as if going to Soloi, under the rocks or cliffs of Elmaion.'[1]

Dioscorides (first century A. D.) refers to the occurrence of the 'amiantos stone' (*λίθος ἀμίαντος*) in Cyprus. He states that it resembles alum-shale[2], and is woven into incombustible fabrics.

Pliny the Elder (23–79 A. D.), who apparently drew his information from the same source as Dioscorides, states that amiantos resembles alum-shale and does not suffer by fire.[3] Elsewhere, in the portion of his Natural History devoted to plants[4], he describes an incombustible fibre under the name of asbestos. He states that it grows in Indian deserts scorched by the sun where no rain falls.

In modern times travellers from the sixteenth century onwards have referred to the existence of abandoned mines of asbestos in Cyprus near the village of Paleandros or Pelendria to the south-east of Mount Troodos, and some mention a village or district known as Amianto.[5] The mineral is stated to be dark green in colour and shining, thus resembling chrysotile more than the asbestos of mineralogists. Gaudry (loc. cit.) also refers to the occurrence of asbestos, and Bergeat[6] expressly mentions that the serpentine is penetrated by veins of chrysotile, though he does not refer to the fact of their having been worked.

In the map of the island surveyed by Lord (then Captain) Kitchener the stream flowing southward to the east of Pelendria is named Amiandos, and a locality on it is described as Mylos tou Amiandou (the Mill of the Amiandos), probably the site of a former watermill. There is apparently no village or district known as Amiandos or Amianto.

not appear to occur elsewhere; it has been translated 'coloured' instead of 'skin-like'.

[1] *Γίγνεται δὲ ὁ λίθος οὗτος καὶ ἐν Καρυστῷ μέν, ἀφ' οὗ καὶ τοὔνομα ἔλαβεν. Πολὺς δὲ ἐν Κύπρῳ καταβαινόντων ἀπὸ τοῦ Γεράνδρου ὡς ἐπὶ Σόλους πορευομένοις ἐν ἀριστερᾷ, τοῦ Ἐλμαίου ὑποκάτω πετρῶν* (loc. cit.).

[2] *Λίθος ἀμίαντος γεννᾶται μὲν ἐν Κύπρῳ στυπτηρίᾳ σχιστῇ ἐοικώς.* Dioscorides, *Περὶ ὕλης ἰατρικῆς*, Bk. v, par. 156.

[3] 'Amiantus, alumini similis, nihil igni deperdit.' Caius Plinius Secundus, 'Historia Naturalis,' Bk. xxxvi, chap. 31.

[4] op. cit., Bk. xix, chap. 4. See also Bk. xxxvii, chap. 54.

[5] J. A. Gaudry, 'Géologie de l'Île de Chypre,' Mém. Soc. Géol. de France, 1862, sér. 2, vol. vii, p. 269; Eugen Oberhummer, 'Die Insel Cypern: Part 1, Quellenkunde und Naturbeschreibung,' München, 1903, p. 188.

[6] Alfred Bergeat, 'Zur Geologie der massigen Gesteine der Insel Cypern,' Min. petr. Mitt. (Tschermak), 1892, vol. xii, p. 298.

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I am indebted to Professor Wyndham Dunstan for the opportunity of examining some of the mineral from the ancient mines on the south-east of Mount Troodos. It is similar in appearance to the Canadian chrysotile, the principal asbestos of commerce, and like it has its fibres at right angles to the veins in which it occurs, but it is shorter in staple than most specimens from the quarries at Thetford or Black Rock. It is pale green in colour, but shows no perceptible pleochroism. It has an extinction parallel to the fibre, the light vibrating in that direction having the least velocity. After drying in a hot air bath it is strongly stained by rhodamine.

An analysis[1] by Mr. G. S. Blake, of the Scientific and Technical Department of the Imperial Institute, gave the following result. The theoretical composition of the mineral and an analysis of a specimen from Broughton near Thetford, Quebec, are added for comparison.

	Near Mount Troodos, Cyprus.	Broughton, Quebec.	Theoretical composition.
SiO_2	... 40·54	... 40·57	... 43·48
Al_2O_3	... 1·09	... 0·90	... —
FeO	... 4·87	... 2·81	... —
MgO	... 39·02	... 41·50	... 43·48
H_2O (+100° C.)	... 13·47	... 13·55	... 13·04
H_2O (−100° C.)	... 1·13	... —	... —
	100·12	99·33	100·00

The mineral has therefore the composition of a somewhat ferruginous serpentine ($H_4Mg_3Si_2O_9$).

There can be little doubt that the material examined came from the locality referred to by Sotakos. Unfortunately, neither Elmaion nor Gerandros is referred to by other classical authors, and the names are no longer in use. Oberhummer[2] suggests that the former is the peak to the east of Mount Troodos, known as Adelphi or Madhari, and that Gerandros is represented by the mediaeval and modern Paleandros[3] or Pelendria.

[1] Bulletin of the Imperial Institute, 1905, vol. iii, p. 281.

[2] loc. cit. and 'Studien zur alten Geographie von Kypros,' Abhand. aus dem Gebiet der klassischen Altertums-Wissenschaft, W. von Christ dargebracht, München, 1891, p. 102.

[3] Possibly Paleandros represents a play on words on the original name of the village which had, it need scarcely be said, no connexion with γῆρας, old age. The form 'Paleandros' is used by G. Mariti, 'Voyage dans l'isle de Chypre,' 1791, vol. i, p. 27.

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At the present day the natives of the island call the mineral ταμπακόπετρα, or cotton-stone, which recalls the κάρπασος of the ancients. Amiandos is said also to be used.[1] The correct expression in modern Greek is ἀμίαντος λίθος, which is practically the form used by Dioscorides; but in the latter part of the eighteenth century the term 'caristia' was still employed.[2]

The modern use of both asbestos and amiantos in the sense of flexible mineral fibres appears to be due to Pliny, who unfortunately seems to have been much worse informed on the subject than his contemporaries or his predecessors. The employment of the word asbestos in this sense seems to have been quite unwarranted. It signifies 'unquenched by water', and in both ancient and modern Greek is appropriately applied to quicklime. At the time when Pliny wrote the usual term for flexible fibrous minerals was, as we have seen, 'Karystios lithos,' though 'lithos amiantos' appears to have been occasionally, but not always, applied to chrysotile from Cyprus. Amiantos means 'untainted', and may have been applied to the mineral because it was cleansed by fire, a recognized symbol of purification in religious rites. This is the accepted view, but I cannot help thinking it possible that the name was first given to the stream which still retains it, for it is an epithet that was frequently applied to water, and that it was afterwards transferred to the mineral found in the vicinity.

It is, as we have seen, probable that not only the mineral from Cyprus, but also that from Karystos was really chrysotile, and that in ancient as well as in modern times it was fibrous serpentine, and not fibrous tremolite, that was mainly employed for spinning and weaving.

The use of the word 'amiantos' in modern times presents some points of interest. In the Romance languages it has taken, to a large extent, the place of asbestos, while by the early German and French mineralogists[3] it was restricted to the finer and more flexible forms which included what is now known as chrysotile-asbestos, and they would undoubtedly have described the mineral from Cyprus under that name. On the other hand, it was scarcely used at all in the language of English science till Mr. George P. Merrill, the mineralogist to the

[1] C. V. Bellamy and A. J. Jukes-Browne, 'The Geology of Cyprus,' Plymouth, 1905, p. 68.

[2] G. Mariti, loc. cit.

[3] L. A. Emmerling, 'Lehrbuch der Mineralogie,' 1793, vol. i, p. 39; and R. J. Haüy, 'Traité de Minéralogie,' 1801, vol. iii, p. 247.

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National Museum at Washington, applied it to the soft flexible varieties[1] of chrysotile which are commercially known as asbestos, and there is much to be said for this use of the word.

I am indebted to Mr. G. F. Hill, of the Coins and Medals Department of the British Museum, for valuable criticism and advice from the standpoint of Greek scholarship.

[1] George P. Merrill, 'Notes on asbestos and asbestiform minerals,' Proc. U.S. National Museum, 1895, vol. xviii, pp. 281, 292. He employs the form 'amianthus', but there is no philological warrant for the insertion of the *h*.

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Gnomonic Projections on two planes.

By John W. Evans, LL.B., D.Sc., F.G.S.
Mineralogist to the Scientific and Technical Department of the Imperial Institute.

[Read June 14, 1905.]

THE gnomonic projection in which the faces of crystals are represented by the points where their normals through a fixed point—the centre of projection—meet a plane—the plane of projection—is already widely used by crystallographers. I propose in the following pages to show the advantages of the simultaneous use of two such planes of projection.

It is in most cases convenient for the two planes to be at right angles, and for the centre of projection to be at an equal (unit) distance from each. Circumstances, however, in some cases render it desirable to vary these conditions. When the planes are at right angles, one may conveniently be described as the horizontal plane, and the other as the vertical plane.

In the diagrams, the projections of face-normals, and other points, on the horizontal plane are denoted by capital letters, and those on the vertical plane by small letters. Projections of zone-planes, and other lines, on the horizontal plane are represented by continuous lines, or, if there be two successive positions of the horizontal plane, those on one by continuous and those on the other by discontinuous lines; similar projections, and other lines, on the vertical plane are represented by lines of dots. The word projection, except where otherwise stated, is used throughout this paper in the sense of gnomonic projection.

The centre of projection is always designated by C, the foot of the perpendicular from it on the horizontal and vertical planes by P and p respectively, and the base-line or line of intersection of the horizontal and vertical planes by XX'. The perpendiculars from P and p on the base-line meet it at the same point M, and are ordinarily of unit length (12·5 mm. in the accompanying figures).

(1) If the projection of a zone-plane on the horizontal plane be given,

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the projection on the vertical plane can be obtained by the following construction :—

Let TU (fig. 1) be the projection on the horizontal plane and let it meet XX' in U. Draw PQ parallel to XX' and meeting TU in Q, and QR at right angles to XX' and meeting it in R. Then the line pR is parallel to the line CQ (not shown in the diagram) in which the given zone-plane is intersected by a plane through C parallel to the vertical plane. The same zone-plane will intersect the vertical plane in a parallel line, for the lines in which two parallel planes are intersected by a third plane are parallel to one another. If therefore a line Ut be drawn parallel to Rp it will represent the projection of the given zone-plane on the vertical plane.

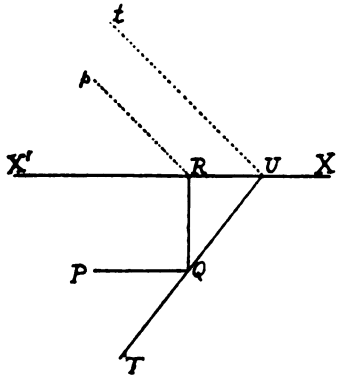

Fig. 1.

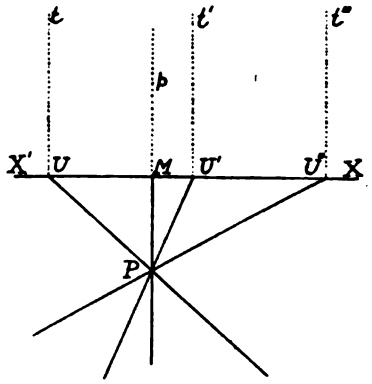

Fig. 1 a.

If the projection of a zone-plane on the horizontal plane pass through P (fig. 1 a), R will be at M on the straight line joining Pp, and the projection on the vertical plane will be at right angles to the base-line XX'. Vice versa, if the projection on the horizontal plane be at right angles to the base-line, the projection on the vertical plane will pass through the point p.

If the projection on the horizontal plane be parallel to the base-line the projection on the vertical plane will also be parallel to the base-line, and its position may be obtained by a projection on a subsidiary vertical plane at right angles to the first.

Let TU (fig. 2 or 2 a) be the projection of the given zone-plane, and let the base-line X_1X_1' of the subsidiary vertical plane meet TU in T' and XX' in O. Join Tp_1 and produce it to meet XX' in t_1. Then

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Ot_1 represents the distance from the horizontal plane of the intersection of the given zone-plane with the original vertical plane. On X_1X_1' make $Ot = Ot_1$, and draw tu parallel to XX', then tu is the projection of the given zone-plane on the vertical plane.

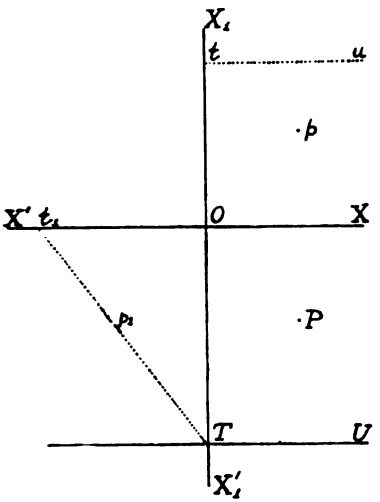

Fig. 2.

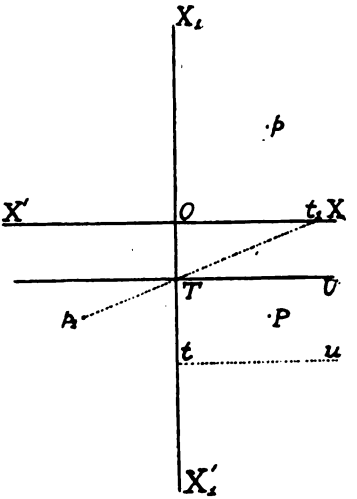

Fig. 2a.

If the projection on the horizontal plane be parallel to the base-line and pass through P, the projection on the vertical plane will be entirely at infinity, and vice versa, if the projection on the vertical plane pass through p, that on the horizontal plane will be entirely at infinity.

(2) Given the projection of a face-normal on the horizontal plane, to find the projection on the vertical plane.

This is solved by taking the projections of any two convenient zone-planes meeting in the face-normal and finding their projections on the vertical plane. The point of intersection of these will be the projection of the required face-normal.

(3) The projection of zone-planes and face-normals on an inclined plane may be found by taking a vertical plane at right angles to the horizontal and inclined planes. The projections on the vertical plane are first found and thence those on the inclined plane. If the inclined plane be at the same distance from the centre of projection as the horizontal plane, it may be considered as a new horizontal plane obtained from the old horizontal plane by rotation about a horizontal axis through the centre of projection.

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(4) Given the projection of a zone-plane T_1U_1 on the horizontal plane, to find its projection on another plane obtained by rotating the first through an angle θ about a horizontal axis through the centre of projection.

Draw a vertical plane at right angles to the axis of rotation Cp, and let the base-line X_1X_1' meet T_1U_1 at U (fig. 3). Draw P_1Q_1 parallel, and Q_1R_1 at right angles to X_1X_1'. Then U_1t, parallel to R_1p, will be the projection of the zone-plane on the vertical plane. Draw the line pM_2 making an angle θ with P_1M_1p, and let $pM_2 = pM_1 =$ unity. Through M_2 draw X_2X_2' at right angles to pM_2, meeting pR_1 in R_2 and tU_1 in U_2. Draw Q_2R_2 at right angles to X_2X_2' and equal to unity. Then Q_2U_2 is the projection of the given zone-plane on the new horizontal plane.

For both the straight lines CQ_1 and CQ_2 pass through C and are parallel to pR_1; they are therefore the same straight line. Q_2 is therefore a point on the required projection on the new horizontal plane, and the same is the case with U_2.

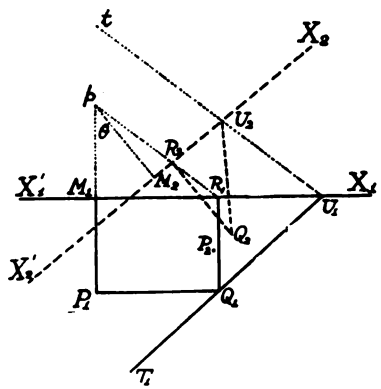

Fig. 3.

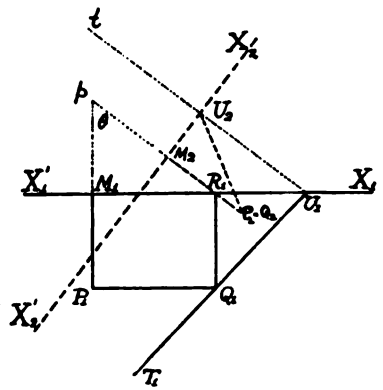

Fig. 3 a.

If the line pM_2 coincide with the line pR_1 the construction is somewhat simplified as shown by the accompanying diagram (fig. 3 *a*). The second horizontal plane will then be at right angles to the line CQ_1 and the point Q_2 will coincide with the point P_2, so that CP_2 is the line CQ_1 in a vertical position with regard to the new horizontal plane. P_2U_2 is therefore the projection required.

(5) The position of the projection of a face-normal after rotation may be obtained by considering it as the point of intersection of the pro-

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jections of two convenient zone-planes, and finding the positions of these, and consequently of their intersection, on the second horizontal plane.

(6) To find the angle between any two face-normals whose projections are given.

The horizontal plane is rotated round the projection of the common zone-plane till it passes through the centre of projection and the face-normals. The true angle between these will then be obtained. This is, in fact, the usual construction. Let U and U' (fig. 4) be the projections of the face-normals. Then C_2U and C_2U' are the positions of the face-normals in the horizontal plane after rotation, and the angle UC_2U' is the true angle between them.

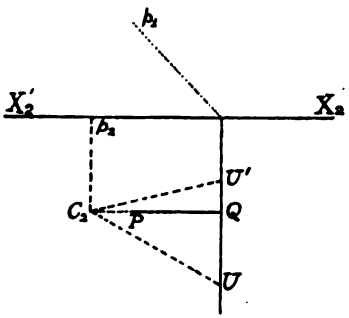

Fig. 4.

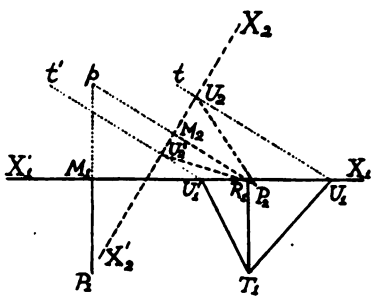

Fig. 5.

(7) Given the projection of a face-normal and a zone to which it belongs, to find the projection of another face-normal in the zone making a given angle with the first.

This is solved on the same principles as the previous problem.

(8) To find the angle between any two zone-planes whose projections are given.

Let the projections of the zone-planes be T_1U_1 and T_1U_1' (fig. 5) intersecting in T_1, the projection of their common face-normal. Assume a vertical plane with a base-line X_1X_1' parallel to the line P_1T_1, and intersecting the projections of the given zone-planes in U_1 and U_1'. Draw T_1R_1 at right angles to X_1X_1' intersecting it at R_1. Then U_1t and $U_1't'$, parallel to R_1p, will be the projections of the given zone-planes on the vertical plane.

Rotate the horizontal plane about Cp (the straight line through the

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centre of projection at right angles to the vertical plane) through the angle M_1pR_1 so that it may take up a position at right angles to the line CT_1. The new base-line will then be the line $X_2M_2X_2'$ drawn at right angles to pR_1 at unit distance pM_2 from p. Let it intersect U_1t and $U_1't'$ in U_2 and U_2'. In pR_1 make M_2P_2 equal to unity.

Then CP_2 is the same straight line as CT_1, and P_2U_2 and P_2U_2' are the projections of the given zone-planes on the new horizontal plane. They are therefore lines in which those zone-planes meet a plane at right angles to their line of intersection, and the plane angle between them is the angle between the zone-planes.

(9) Given the projection of a zone-plane and that of a face-normal in it, to find the projection of another zone-plane including this face-normal and making a given angle with the first zone-plane.

This is solved on the same principle as the last problem. The horizontal plane is tilted till it is at right angles to the common face-normal. The projection of the required zone-plane is drawn at the given angle, and the horizontal plane rotated back to its first position.

(10) By the help of these constructions it is possible to solve spherical triangles where two sides and the included angle are given, or two angles and the included side, or two sides and the angle opposite one of them. The sides are represented by zone-planes and the angular points by face-normals.

In the last case the face-normal corresponding to the given angle is brought into the position CP and the projections of the two adjoining sides are drawn. On the projection of the adjoining side whose dimensions are given a corresponding length[1] is measured off (No. 7), and in this way the position of the face-normal is obtained which corresponds to the angle between the two sides whose dimensions are given. This face-normal is now brought into the position CP and a circle described round its projection at a distance representing the length of the side opposite the known angle. The intersections of this circle with the projection of the side of unknown length give the two spherical triangles satisfying the required conditions.

(11) Given the projection of a face-normal, to find the locus of the projections of face-normals making a given angle with it.

Let T_1 (fig. 6) be the projection of the given face-normal. Rotate the horizontal plane so as to bring the face-normal CT_1 into a vertical position CP_2. Draw a circle round P_2 as centre at a distance corre-

[1] Which would be equal in this position to the tangent of the circular measure of the side.

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sponding to the angle θ, and let D_2 and D_2' be the extremities of the diameter parallel to X_2X_2'. Find the projections D_1 and D_1' on the original horizontal plane of the face-normals of which D_2 and D_2' are the projections on the second horizontal plane, then D_1D_1' is the major axis of the ellipse that forms the required locus and E_1 is its centre. Two other points K_1 and K_1' on the ellipse can be found on the line through T_1 at right angles to P_1T_1 by the method of (7), and from these data the ellipse can easily be constructed by the help of the auxiliary circle $D_1N_1M_1D_1'$.[1]

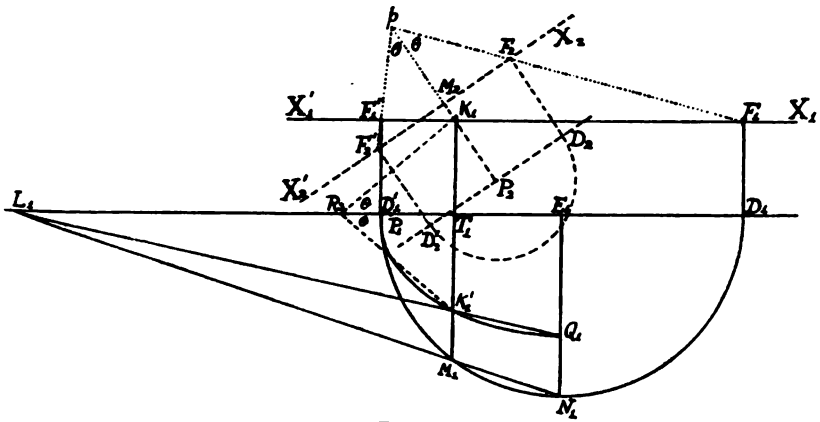

Fig. 6.

(12) By the help of this problem a spherical triangle can be solved in which the three sides are given. The other cases, where three angles or two angles and the side opposite one of them are given, can be solved by taking the polar triangle.

(13) Given the projection of a twin-axis and a zone-plane, to find the position of the corresponding twinned zone-plane.

The horizontal plane is rotated so as to bring the twinning axis into the position CP. The twinned position of the given zone-plane will be the parallel line on the opposite side of and at an equal distance from P. The horizontal plane can then be rotated back to its original position and the projection of the twinned zone-plane found in the usual manner.

[1] Let N_1 be any point on the circle, and M_1 the point on the circle where $K_1'T_1$ (produced) intersects it. Draw N_1M_1 meeting D_1D_1' in L_1. Draw L_1K_1' meeting at Q_1 the perpendicular from N_1 on D_1D_1'; then Q_1 is a point on the ellipse. In the diagram (fig. 6) Q_1 is the extremity of the minor axis of the ellipse.

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(14) Given the projection of a twin-axis and that of a face-normal, to find the projection of the normal of the twinned face.

This can be done by taking two convenient zone-planes intersecting in the face-normal and determining their corresponding twinned zone-planes. The intersection of these projections will give that of the twinned face-normal.

All these constructions will apply to *linear projection*, if for zone-planes and face-normals there are substituted planes and lines parallel to the faces and edges of the crystal and passing through the centre of projection. The planes and lines of the linear projection are in fact the polar representatives of the face-normals and zone-planes of the gnomonic projection of the same crystal.

Both linear and gnomonic projection are of great convenience in the drawing of crystals, as they give at once the direction of the edges of the crystal in an orthogonal projection on the horizontal plane. In the gnomonic projection these are given by the lines drawn from P at right angles to the projection of the zone-plane: in the linear projection, by the lines joining P to the points representing the crystal-edges.

By rotating the horizontal plane through a convenient angle about any convenient axis it is easy to get a projection from which a drawing of the crystal may be obtained in a position which is adapted for showing its shape and symmetry.

In some cases there are other graphic solutions which involve fewer lines than those I have given in this paper, but the rationale is often not very obvious except to the expert mathematician, and to most mineralogists and students they will not afford so much insight into the spacial relations of the faces and zones of a crystal. In actual practice, too, some of the lines shown in the diagrams illustrating this paper may be omitted, and by judicious procedure the same lines are available for several different constructions. When two or three zones have been dealt with, the remainder can be worked out from them with only occasional resort to three dimensional methods.

I am indebted to Mr. T. W. Tyrrell for carefully executing the drawings illustrating this paper.

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Determination of the optic axial angle of biaxial crystals in parallel polarized light.

By JOHN W. EVANS, LL.B., D.Sc., F.G.S.
Mineralogist to the Scientific and Technical Department of the Imperial Institute.

[Read November 14, 1905.]

IT will in the first place be assumed for the sake of simplicity that the crystal to be investigated is immersed in a liquid having a refractive index as nearly as possible equal to the intermediate refractive index (β), so that light travelling along the optic axis [1] is not appreciably refracted on entering or leaving the crystal.

The observation is made in parallel light between crossed nicols, which are rotated together till a position of extinction is reached, when the directions of vibration of the nicols will be parallel to those in the crystal. If the latter be now rotated on an axis parallel to one of these directions, it will in general show light throughout the revolution, except in the original position and that opposite to it. Occasionally, however, it will remain dark throughout; in that case the axis of rotation is the bisectrix of an optic axial angle. Sometimes, on the other hand, it will remain dark except in four positions opposite to each other in pairs; the axis of rotation is then the optic normal, and the plane in which the rotation takes place the optic axial plane. The four positions correspond to the two optic axes; and a determination of the angles between these positions would give the acute and obtuse optic axial angles, but the observation is not a very satisfactory one.

If the crystal be now returned to its original position, and the nicols rotated through 45°, the crystal will become light. With the nicols in this position it is easy to ascertain by means of a gypsum-plate or quartz-wedge whether the axis of rotation be parallel to the vibrations of the slow or fast wave-surface, in other words, whether it be positive or negative.

If the crystal be now rotated as before, it will, if the axis of rotation be either a bisectrix or optic normal, remain light through the entire revolution; but, if the sign of the axis of rotation be observed, a differ-

[1] Or, to use more accurate language, light whose wave-surface is at right angles to a binormal.

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ence will be noted in the two cases. If the axis of rotation be a bisectrix, the sign of the axis of rotation will remain the same throughout, and though the relative retardation between the two wave-surfaces will vary from point to point, it will never be zero. If, on the other hand, the axis of rotation be the optic normal, its optical sign will change four times during a revolution at positions corresponding to the optic axes; and at these positions the relative retardation will be zero.

The angles between these positions are the optic axial angles, and the sign of the axis of rotation in the interval between any two optic axes is the same as that of the bisectrix of the angle between them.

The exact points where the relative retardation is zero may be determined by inserting either a gypsum-plate showing a sensitive tint—preferably the red of the first order—or a double quartz-wedge such as is described on p. 91 of the present volume. The wedge should be placed in the focus of the eye-piece. If the plate be used, the position of an optic axis is marked by the appearance of the characteristic tint, while in the case of the wedge it is indicated by the exact coincidence of the bands on the two sides of the wedge. If the light used be strictly parallel, the quartz-wedge will give results equal, if not superior, to those given by the methods in which convergent light is employed. For the most accurate work mono-chromatic light should, I need not say, be used.

If the crystal substance is not immersed in a liquid of the required refractive index, it should have one or more pairs of parallel plane surfaces, and the refractive index between it and the medium in which it lies should be such as to allow of the emergence of two optic axes whose apparent positions may be determined in the manner described above. Thence their true positions and the angle between them may be calculated in the usual manner.

The principal advantage of the method described in this paper is that it can be employed in the case of minerals occurring in a thin section of a rock. In strongly convergent light this can only be turned through a comparatively small angle, but in parallel light under a low power it can be rotated to any required extent.

It is preferable to employ a microscope in which both nicols revolve together. With it should be used a stage-goniometer or 'Universal-Drehapparat[1],' which allows of two rotations, one about an axis at right angles to the axis of the microscope, and the second about an axis at

[1] The 'Universal-Drehapparat' designed by C. Klein is well suited for use with this method; see H. Rosenbusch, 'Mikroskopische Physiographie der Mineralien und Gesteine,' vol. i, part 1, 4th edition, by E. A. Wülfing, 1904, pp. 204–205.

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right angles to that of the first as well as to the plane of the glass slip supporting the thin section. It should be fitted with an arrangement for holding the glass slip, so that any desired portion of the section may be retained at the centre of rotation. The glass slip should be of less than the usual size. Though not absolutely necessary, it is very desirable to employ some form which allows of immersion in liquid. Instruments in which glass hemispheres are employed instead of immersion are unsuitable, as these interfere with the parallelism of the light.

The rock slide must be searched to find a crystal cut at right angles to the optic axial plane and which allows the emergence of two optic axes in the medium employed. This search may be carried out in parallel light by looking for a section which gives, on rotation about the axis at right angles to the axis of the microscope, the phenomena described above as characteristic of a rotation on the optic normal; but it will usually be more convenient in the first place to use convergent light, when the symmetrical 'pendulum movement' of the dark brush or 'isogyre', will, as F. Becke[1] has shown, indicate a section cut at right angles to the optic axial plane, and thus one suitable for further examination in parallel light for finding the positions of emergence of the optic axes.

In conclusion, I have only to add that it is to E. S. Fedorov[2] that we owe the principle of the examination of the optical characters of a crystal by rotation in different directions in parallel polarized light, of which principle the method described in this paper is only a special development.

[1] F. Becke, 'Die Skiodromen,' Min. petr. Mitt. (Tschermak), 1905, vol. xxiv, pp. 1–84.

[2] Zeits. Kryst. Min., 1893, vol. xxii, p. 229; 1896, xxvi, p 225; 1896, xxvii, p. 337; 1898, xxix, p. 604.

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Geikielite and the ferro-magnesian Titanates.

By T. Crook, A.R.C.Sc.I., F.G.S., and B. M. Jones, B.A. (Oxon.)
Assistants in the Scientific and Technical Department of the Imperial Institute.

[Read January 23, 1906.
Communicated by permission of the Director of the Imperial Institute.]

In connexion with the systematic examination of the minerals of Ceylon, which is being conducted in the Scientific and Technical Department of the Imperial Institute, the authors have recently examined a large quantity of coarse gem-gravel refuse obtained from the Balangoda and Rakwana districts of Ceylon.

The material varies somewhat in character, but zircon generally predominates, while tourmaline, corundum, and pleonaste are fairly abundant. Among other minerals present in noticeable quantities are geikielite, picroilmenite, ordinary ilmenite, rutile, and fergusonite, all of which are generally in the form of rounded or sub-angular pebbles.

This association of the members of the geikielite-ilmenite series seemed to be a matter of some interest, especially on account of the fact that among the specimens examined there occurred varieties having specific gravities intermediate between those of geikielite and picroilmenite.

Geikielite.

Physical characters.—The specimens identified as geikielite are quite similar in their physical characters to those first described by Mr. Allan Dick.[1] They have a dull black appearance on worn surfaces, but freshly fractured surfaces are jet-black and show a somewhat vitreous lustre. The cleavage is rhombohedral, the angles between the cleavage-planes being about 93½°. This appears to be a true cleavage and not a parting. None of the specimens shows any trace of twinning. The cleavage-faces when perfectly fresh show a metallic-adamantine lustre, but generally they are dulled by a thin film of titanium dioxide, even in the freshest specimens. It is only when this film is present that the plum-coloured hue described by Mr. Dick can be seen. The fracture is generally uneven, but occasionally sub-conchoidal. The hardness is 6.

The streak is purplish-brown, and not black as stated by P. von

[1] Min. Mag., 1893, vol. x, p. 145.

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Sustschinsky.[1] When the powder is finely ground in an agate mortar, its colour is deep purple and quite characteristic. The mineral is opaque, except in thin splinters under the microscope, these being translucent and of a deep reddish-purple colour. The splinters give a uniaxial figure of negative sign, and are non-pleochroic. Geikielite is slightly magnetic, but less so than picroilmenite and much less so than common ilmenite.

Chemical composition.—In the analysis published by Dick, only 3·8 per cent. of iron oxide was recorded. In 1902, Sustschinsky, who examined some geikielite from Ceylon having the same physical characters as that described by Dick, recorded 9 per cent. of iron oxide. The following are the two analyses:—

	Dick.	Sustschinsky.
TiO_2	67·74	61·32
FeO	3·81	2·03
Fe_2O_3	—	7·75
MgO	28·73	28·95
	100·28	100·05
Specific gravity ...	3·98–4·0	3·976

The results of a considerable number of analyses of the material examined by the present authors confirm the analysis recorded by Sustschinsky. The following are two typical analyses of geikielite poor in iron:—

	I.	Molecular ratios.	II.	Molecular ratios.
TiO_2	64·78	... 0·809	... 64·41	... 0·805
FeO	5·92	} 0·110[2]	... 5·44	... } 0·114[2]
Fe_2O_3	2·22	... }	... 2·77	... }
MgO	27·90	... 0·697	... 27·90	... 0·697
	100·82		100·52	
Specific gravity ...	3·89	...	... 3·97	

The specimen used for analysis I is slightly altered and shows leucoxene along the cleavage-cracks; hence the comparatively low specific gravity. The material II was quite fresh, and the specific gravity given

[1] 'Beiträge zur Kenntniss des Geikielith, Ilmenit und Hämatit,' Zeits. Kryst. Min., 1902, vol. xxxvii, p. 57; abstract Min. Mag., vol. xiii, p. 307.

[2] All the iron is calculated as ferrous oxide.

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above may be taken as representing the true value for unaltered geikielite containing 8·2 per cent. of iron oxide.

It seemed unlikely that these specimens could differ chemically from those examined by Mr. Dick, seeing that they were so very similar in all other respects. Accordingly, Mr. Dick kindly permitted his material to be re-examined. The fragments consisted partly of rutile, but this was coarse enough to allow of its separation. A portion of geikielite free from rutile gave the following analysis:—

	III.
TiO_2	63·77
FeO	6·34
Fe_2O_3	1·93
MgO	28·50
	100·54

From this result it seems probable that the iron oxide was not completely separated from the titanium dioxide in the original analysis.

The method of analysis adopted was fusion of 0·3 to 0·5 gram of the finely powdered mineral with potassium hydrogen sulphate, the solidified cake being dissolved in cold water acidified with sulphuric acid. After diluting to one litre and reducing with a little sodium sulphite, the whole was boiled from six to seven hours, water being added at intervals to replace that lost by evaporation. The precipitated titanium dioxide was filtered off, dried, ignited with a few grains of ammonium carbonate, and weighed. The titanium dioxide thus obtained generally contained about 2 per cent. of iron oxide, and sometimes as much as 7 per cent.; but it rarely contained more than a trace of magnesia. The process of fusion was repeated to separate completely the iron oxide and magnesia. A third fusion was necessary in two cases only. The filtrate from the titanium dioxide was tested with hydrogen peroxide to make sure that all the former was precipitated; then ammonium chloride was added, and the total iron and magnesium determined in the usual way. To determine the ferrous iron, a portion of the powdered mineral weighing about 0·3 gram was decomposed by a mixture of hydrofluoric and dilute sulphuric acids, in the absence of air, and the solution obtained titrated with potassium permanganate.

Geikielite with only 8 per cent. of iron oxide is comparatively rare in the gem-gravels. More commonly, varieties occur which are somewhat richer in iron, containing 10 to 14 per cent. of the oxides. These have a somewhat higher specific gravity, as one would expect. They also

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diminish somewhat in transparency, while the streak and colour of the powder deepen in shade as the percentage of iron increases. The following analyses illustrate the varying composition of these specimens:—

	IV.	V.[1]	VI.	VII.	VIII.	IX.	X.
TiO_2 ...	63·94	64·03	62·49	62·25	61·60	60·87	60·02
FeO ...	10·09	12·14	10·70	11·58	7·79	6·03	5·81
Fe_2O_3 ...	0·25	—	3·54	—	4·95	5·69	6·80
MgO ...	25·79	24·66	23·60	26·03	26·31	27·29	27·79
	100·07	100·83	100·33	99·86	100·65	99·88	100·42
Sp. gr.	4·01	4·11	4·01	3·91	3·90	3·87	3·79

The material of analyses IV and V was fresh; that of VI slightly decomposed along the cleavages; while in VII, VIII, IX and X it showed growths of leucoxene increasing in amount as the specific gravity diminishes.

From these results it is seen that ferric iron may or may not be present, but ferrous iron is always present, and generally in much larger quantity than the ferric. Further, the ferric oxide appears to be sometimes of primary and sometimes of secondary origin. In some instances (as in Nos. VIII, IX, and X) the ferrous iron and magnesia unite with the titanium dioxide, leaving a surplus of ferric oxide. When this is the case, it seems reasonable to explain the presence of ferric oxide as an isomorphous replacement of the geikielite molecule. In other cases, however (as in Nos. I, II, IV, and VI), there is a deficit in the sum of ferrous oxide and magnesia molecules, a deficit which is remedied by reducing (in calculation) such ferric oxide as is present to a ferrous state, and adding this to the sum of existing ferrous oxide and magnesia. In these cases it appears probable that the ferric oxide is secondary and that it has arisen by oxidation from the ferrous state. In still other cases both primary and secondary ferric oxide appear to be present. It is only on this assumption that many of the analytical results can be explained.

It is, however, a noteworthy fact that a specimen may show a considerable amount of the leucoxene decomposition product, though containing no secondary ferric oxide; on the other hand, apparently fresh specimens may contain this secondary ferric oxide.

[1] No. V contained a trace of manganese.

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In general, the *specific gravity* increases with the percentage of iron, but within narrow limits the variations are complex and difficult to understand, though the reduction of the specific gravity by the partial decomposition along the cleavages accounts for most peculiarities. Assuming equal molecular volumes for the different members of the geikielite-ilmenite series, and taking the specific gravity of ilmenite ($FeTiO_3$) as 4·7, the specific gravity of geikielite free from iron ($MgTiO_3$) should be 3·7. In this connexion the following comparison is of interest as illustrating the relation between specific gravity and composition in some of the least altered specimens:—

	Calculated sp. gr.	Observed sp. gr.
$(Mg,Fe)TiO_3$ with 8 per cent. FeO	3·87 ...	3·97
„ „ 14 „ „	3·96 ...	4·11
„ „ 27 „ „	4·28 ...	4·30
„ „ 34 „ „	4·42 ...	4·44

It is probable that neither the calculated nor the observed specific gravities are correct in the second place of decimals, as the specific gravity of ilmenite is uncertain and the specimens are liable to decomposition. But such as the numbers are, they appear to indicate that the molecular volume for the geikielites is somewhat smaller than that for the ilmenites.

Alteration products of geikielite.

Rutile.—The specimens are generally free from visible intergrowths with other minerals. One specimen, however, is associated with rutile as an alteration product. It is sub-angular in shape and weighed about 16 grams; it appears to have been broken from a much larger specimen. Except on the fractured surface, which has the characteristic thin film of titanium dioxide, the specimen is covered with a shell of rutile varying in thickness from one to two millimetres. The surface of contact between the geikielite and the rutile is very irregular, and there can be no doubt that the latter has resulted from the alteration of the former. The specimen is quite free from intergrowth, and the rutile is confined to the external surface.

Leucoxene.—This is white or yellowish-white in colour, opaque, and for the most part apparently amorphous. It is the commonest alteration product of geikielite and is similar in appearance to that familiar on the cleavage-planes of ilmenite. It is generally confined to the cleavage-planes; one specimen was found, however, a portion of which was almost

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completely decomposed, and this furnished about a decigram of material which gave the following analysis:—

TiO_2	81·3
Fe_2O_3	6·4
CaO	3·0
MgO	trace
SiO_2	4·2
H_2O	5·6
	100·5

In this case the leucoxene consists mainly of amorphous titanium dioxide. The ferric oxide is probably present as limonite, while the lime and silica are probably in combination with a portion of the titanium dioxide as sphene.

Sphene.—This occurs as colourless, translucent granules intimately associated with the leucoxene in the cleavage-cracks. These granules show the optical characters of sphene, and their identification as such is confirmed by the above analysis of the leucoxene.

Limonite.—This was observed in the cavities of much decomposed specimens.

Picroilmenite.

Picroilmenite[1], or magnesian ilmenite, appears to occur in considerable quantities in the Balangoda district. It has a specific gravity of 4·25, when fresh; two specimens gave the following analyses:—

	XI.	XII.
TiO_2...	57·64	56·08
FeO	16·57	24·40
Fe_2O_3	10·17	5·43
MgO...	15·56	14·18
	99·94	100·09
Specific gravity ...	4·17	4·25

In specimen No. XI, the ferric oxide appears to be partly primary and partly secondary, while in No. XII it is all primary. The mineral is thus very similar in composition to the magnesian ilmenite of

[1] P. Groth, 'Tabell. Übers. d. Mineralien,' 4th edition, 1898, p. 143.

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Warwick, New York, analysed by C. F. Rammelsberg in 1858, and by S. L. Penfield and H. W. Foote[1] in 1897.

Notwithstanding its high percentage of iron, it is translucent in very thin splinters under the microscope and shows a deep purple-red colour very similar to that of geikielite. Its streak, and the colour of its powder in the mass, are similar to those of geikielite in tint, but much darker in shade. Its hardness is 6, and, like geikielite, it appears to be about half a degree, on Mohs's scale, harder than ilmenite.

In all its properties it is much more akin to geikielite than to common ilmenite. Its composition generally corresponds to the formula $(Fe,Mg)TiO_3$, where $Fe : Mg = 1 : 1$; this fact, together with the intermediate character of its general properties, makes it advisable to regard picroilmenite as the middle member of the series of ferro-magnesian titanates. Those members of the series containing less magnesia and more iron oxide than picroilmenite should be classed as ilmenites, while those with more magnesia and less iron should be classed as geikielites.

Summary and Conclusions.

1. Up to the present no geikielite has been found containing less than 8 per cent. of iron oxide.

2. For this reason the formula $(Mg,Fe)TiO_3$ represents the composition of geikielite more correctly than the formula $MgTiO_3$.

3. Picroilmenite is closely related to geikielite in its general properties.

4. It is advisable to divide the ferro-magnesian titanates into ilmenites and geikielites, and to regard picroilmenite as the middle member of the series.

5. It seems likely that, considering the association in the present instance of geikielite and picroilmenite, many specimens commonly classed with the latter may turn out on closer examination to be geikielite.

6. The alteration products of geikielite are similar to those of ilmenite, and include rutile, amorphous titanium dioxide (leucoxene), sphene, and limonite.

[1] Amer. Journ. Sci., 1897, ser. 4, vol. iv, p. 108.

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Dundasite from North Wales.

By G. T. Prior, M.A., D.Sc., F.G.S.

Assistant in the Mineral Department of the British Museum.

[Read March 15, 1905.]

THE mineral dundasite was first described by W. F. Petterd in 1893, in a 'Catalogue of Minerals known to occur in Tasmania'[1]. It was found in small, silky, milk-white, spherical aggregates incrusting a 'ferro-manganese gossan' at the Adelaide Proprietary mine, Dundas. In this catalogue, and in a subsequent one dated 1896, it was stated, as the result of qualitative tests, to be a hydrated carbono-phosphate of lead and aluminium; but a quantitative analysis (see below under II), made later by S. Pascoe, showed that the mineral is a hydrated carbonate of lead and aluminium, and that the traces of phosphoric acid were due to a thin coating of pyromorphite. In this analysis the water and carbonic acid were determined together, by loss on ignition, and consequently hitherto no chemical formula has been attributed to the mineral. In his 'Notes on unrecorded and other minerals occurring in Tasmania'[2], in which this analysis appears, Mr. Petterd mentions another locality for dundasite in Tasmania—viz. the Hercules mine, Mt. Read, where it was found in patches on a mass of cellular quartz through which were scattered crystals of cerussite and gibbsite.

At a recent meeting of the Mineralogical Society, Mr. H. F. Collins showed me specimens of a mineral which had been found[3] in small, silky, white tufts upon cerussite in the 23 ft. level, Francis lode, Welsh Foxdale mine, near Trefriw, Carnarvonshire. These specimens he kindly placed at my disposal for determination.

Chemical analysis showed that the mineral must be referred to dundasite. In physical characters it is precisely similar to the Tasmanian mineral, of which a specimen, obtained from Mr. Petterd, is in the British Museum collection. It occurs in small (mostly not more than 1 mm. in diameter), white, spherical aggregates or tufts consisting of a felted mass of minute,

[1] Papers and Proceedings of the Royal Society of Tasmania, for 1893, 1894, p. 26.

[2] Papers and Proceedings of the Royal Society of Tasmania, for 1902, 1903, p. 22.

[3] To Mr. G. J. Williams, H.M. Inspector of Mines, appears to be due the credit of having first noticed these tufts of a mineral unknown to him on some cerussite specimens from the Welsh Foxdale mine.

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radiating, silky needles. Under the microscope these needles are seen to be fairly strongly refractive (equal to mono-bromo-naphthalene, 1·66) and doubly refractive (some of the larger needles show yellow and red of the first order), to give straight extinction, and to compensate across their length with a quartz-wedge cut parallel to the optic axis : no definite optic axial figure was observable through them in convergent light.

In the specimens presented to the British Museum by Mr. Collins, the tufts of dundasite are associated with beautiful, small, glassy spherules, which analysis showed to be allophane; and both these minerals were thickly distributed in the interstices of a mass of loosely cohering, long-prismatic crystals of cerussite.

The material for analysis was obtained by picking out spherules from a quantity of débris, derived apparently from the breaking up of various specimens. Most of these spherules were tinged slightly yellow from impurity of oxide of iron, but otherwise they appeared to be fairly pure and free from cerussite. The result of the analysis is given under I, as compared with that of dundasite from Tasmania under II, while under III is given the theoretical composition corresponding to the formula, $PbH_2(CO_3)_2.Al_2(OH)_6$.

	I. (N. Wales).	Molecular ratios.	II. (Tasmania).	III. $PbH_2(CO_3)_2.Al_2(OH)_6$.
PbO	43·20	... 0·1938	... 41·86	... 45·95
Al_2O_3	21·39	... 0·2093	... 26·06	... 21·07
Fe_2O_3	1·61	... —	... 5·50	... —
CO_2	16·45	... 0·3739	... }	... 18·14
H_2O (above 100°)	13·60	... 0·7556	... } 28·08	... } 14·84
H_2O (at 100°)	1·41	... —	}	}
Insoluble ...	1·80	... —	...	... —
	99·46		101·50	100·00

Weight of material used in analysis 0·2140 gram. The water was determined by Penfield's bulb-tube method, and the carbonic acid was estimated by difference between the water and the total loss on ignition. The density of the mineral was determined, by immersing in methylene iodide diluted with benzol, to be between that of axinite and apatite, i. e. about 3·25. That of dundasite from Tasmania was found to be practically the same. The numbers obtained in the analysis suggest the formula $PbO.Al_2O_3.2CO_2.4H_2O$ or $PbH_2(CO_3)_2.Al_2(OH)_6$.

In physical characters and also in chemical composition the mineral

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shows a close relationship to dawsonite, the hydrated carbonate of sodium and aluminium, to which the formula $Na_2O.Al_2O_3.2CO_2.2H_2O$ has been attributed.

Characters of dundasite:—

Occurs in white, spherical aggregates or tufts of minute, radiating needles. Hardness, 2. Density, 3·25. Lustre, vitreous. Colour, white. Transparent. Refraction and double refraction, fairly strong: needles give straight extinction and are positive. Chemical formula,

$$PbO.Al_2O_3.2CO_2.4H_2O.$$

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Paratacamite, a new oxychloride of copper.

By G. F. Herbert Smith, M.A., F.G.S.

With a chemical analysis by G. T. Prior, M.A., D.Sc., F.G.S.

Assistants in the Mineral Department of the British Museum.

[Read March 15, 1905.]

ABOUT two years ago there was brought to the British Museum a specimen covered with numerous small cubes—so the crystals appeared to be—of the bluish-green colour suggestive of a mineral containing copper. Judged by their form the crystals might be boleite, but a qualitative analysis by Dr. Prior, while revealing the presence of chlorine and copper, showed no trace of lead. A crystal was then removed from the specimen and measured on a goniometer, and the discovery was at once made that these apparent cubes are in reality rhombohedra with an angle of nearly 83° between adjacent faces. Since no previously known oxychloride of copper crystallizes in this form, these crystals were evidently worthy of further investigation. Inquiry elicited the information that the specimen was one of between seven and eight hundred, mostly mineral, specimens which had been collected in Chili by a mining engineer, of the name A. Anabalón y Uryúa; the manuscript catalogue of the collection is dated September 1899. The collection ultimately came into the hands of Mr. F. H. Butler, of London, and, his attention having been directed to these curious crystals, he brought the specimen to the Museum. As it was desirable to accumulate as much material as possible for a complete examination of the properties of this new mineral, all those specimens in the collection which showed any green crystals were examined. Many turned out to be atacamite; but other specimens were found which displayed crystals of the new mineral, all of which were acquired by the Trustees of the British Museum, with the exception of two, which had previously been purchased by Mr. Arthur Russell, who with ready courtesy, which the author gladly acknowledges, lent them for the purposes of this investigation. Altogether ten specimens of the new mineral were discovered, but the crystals employed in the determination of the morphological characters were taken from the best of them, four in number.

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The Herminia mine and the Generosa mine, Sierra Gorda, Chili, are the localities given on the labels for nine of the specimens; the remaining specimen, which exhibits a few minute crystals of the new mineral in conjunction with native gold, comes from the Bolaco mine, San Cristóbal, Chili. The matrices are more or less decomposed, and one specimen in

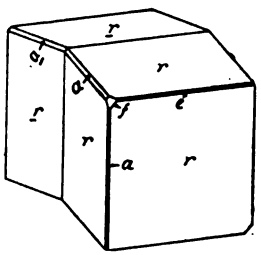

Fig. 1.

Paratacamite. Twinned crystal: Rhombohedral type.

particular is almost falling to pieces. In addition to quartz the associated minerals are galena and caracolite, both of which are much altered. The former has in places disappeared altogether, leaving a reticular arrangement of small square pits; the latter has no doubt been in part affected by the cleansing which the specimens had undergone before reaching the Museum, in order to rid them of the mud and dirt encasing them.

The types of crystals are two in number. In one, as has already been stated, the crystals resemble cubes but are really rhombohedra. Certain edges and corners are often truncated by small faces. Fig. 1 depicts such a rhombohedron twinned about one of its faces; similar crystals are very common. Crystals of the second type differ markedly in appearance from those of the first, and may easily, at a glance, be mistaken for atacamite. They are prismatic in form, being elongated parallel to the edge of a zone [*rfa*], and, since they are invariably twinned about the face of the form *r* lying in this prismatic zone, they simulate orthorhombic symmetry. Crystals of this kind are shown in figs. 2 and 3; the second individuals, which lie at the back and cannot be seen, are in every way similar to the first. When there are no re-entrant angles—and this is frequently the case—nothing suggests on ordinary inspection that these crystals are really twinned. The angles *rf* and *rc* are respectively 52° 55′ and 49° 48′; in the case of a crystal of atacamite, for which it might be mistaken, the angles *bm* and *be* are

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56° 81½′ and 53° 1½′[1]. The difference of a few degrees in the case of the corresponding angles is too small to be detected by the unaided eye. Crystals of atacamite, however, from this district usually show the form

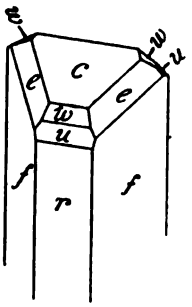

Fig. 2.

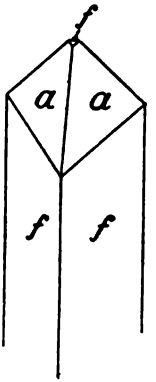

Fig. 3.

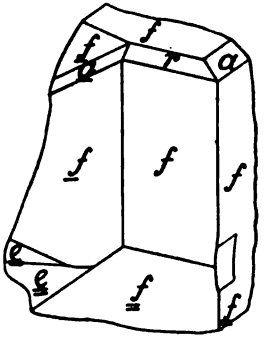

Fig. 4.

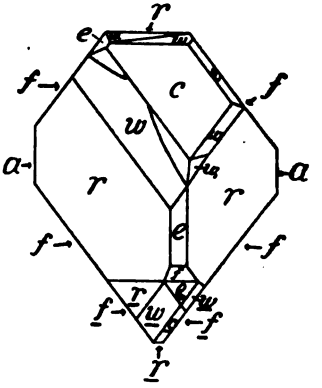

Fig. 5.

Paratacamite. Twinned crystals: Prismatic type.

h (132), which is invariably striated parallel to its intersection with *e* (011), and this form, if present, serves to discriminate the two minerals, since no form similarly striated is displayed by the new mineral.

There is a good cleavage parallel to the principal rhombohedron-

[1] These angles are taken from the author's paper, Min Mag., 1898, vol. xii, pp. 15-25.

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face *r*. Twins with respect to the same face are very common; indeed the prismatic type seems to be invariably twinned. Various types of twin-crystals are illustrated in figs. 1–5. The crystal drawn in fig. 4 is remarkable for the conjunction of three distinct individuals, the faces of which are denoted by letters with no bar, one bar, and two bars underneath respectively. The three contiguous faces of the form *f* are parallel and give on the goniometer a single image. The first and second individuals are related by the ordinary twinning about a face *r*. The first and third are in parallel positions, and possibly the latter may have arisen from independent twinning with respect to the second individual. Another plausible explanation is that a face of the form *a* is the twin-plane, although such a twin has not been otherwise observed. It may be remarked that the line of demarcation between the first and third individuals is parallel to the edge of a zone [*rfa*]. The crystal illustrated in fig. 5 is noteworthy for the vicinal planes accompanying the faces of the form *w*. In two cases it is quite a distinct face (lettered w_1), while in the third it gives an irregular intersection with the corresponding face *w*. The measurements from *c* of the three faces w_1, on this particular crystal relative to the corresponding face *w*, are as follows:—

	Azimuth.	Distance.
w_1	2°20′	29°16′
	0 59	29 15
	2 24	28 17
w	0 0	25 20

and the calculated values for a face of the form (411) are

(411)	0 0	30 37

Thus w_1 lies near the form (411), but so variable is its position on the various crystals measured that no definite symbols can be assigned to it. Its distance from the corresponding face *w* is fairly constant, greater variation occurring in the orientation.

The crystals are mostly small in size, rarely exceeding 2 mm. in any direction; often they are merely needles, less than 1 mm. in length and 0·5 mm. in cross-section.

The name paratacamite has been assigned to the new mineral, because, as the analysis given below shows, the percentage chemical composition is the same as that of atacamite. A certain connexion can be traced between the measurements on crystals of the two minerals made from the respective cleavage-faces, as appears from the following table:—

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TABLE I.

Comparison between the Measurements on Paratacamite and Atacamite.

Paratacamite. Measured from *r* (100).			Atacamite.[1] Measured from *b* (010).		
Form.	Azimuth.	Distance.	Form.	Azimuth.	Distance.
a 0$\bar{1}$1	90° 0′	90° 0′	*c* 001	90° 0′	90° 0′
f 1$\bar{1}$1	„ „	52 55	*e* 011	„ „	53 1½
r 001	41 49	82 49½	*u* 101	41 17½	90 0
e 101	„ „	41 25	*r* 121	„ „	45 11
a 10$\bar{1}$	„ „	−48 35			
e 011	0 0	80 25	*a* 100	0 0	90 0
c 111	„ „	49 48	*m* 110	„ „	56 31½
f $\bar{1}$11	„ „	−63 6½			

Altogether forty-three crystals were measured on the three-circle form of goniometer[2] designed by the author, in every case the reference-pole being a face of the form *r*. In the case of six crystals, in which the face *c* is well developed, measurements were made from this face also, and on some crystals of the type illustrated in figs. 2 and 3 controlling measurements were made from faces of the form *f*.

The observed forms, nine in number, are as follows:—

Form.	Indices. Rhombohedral.	Indices. Hexagonal.	Characters, &c.
c	111	0001	Not always found: generally small, but occasionally large: images distinct.
r	100	10$\bar{1}$1	Occurs on every crystal: large in the rhombohedral type, the faces being distorted and the images consequently blurred, and small in the prismatic type, the images being distinct: a good cleavage parallel to faces of this form: twin-plane.
f	11$\bar{1}$	02$\bar{2}$1	Common: small, almost minute, on the rhombohedral type, and large on the prismatic type: images good.
e	110	01$\bar{1}$2	Common, but small: images distinct.
a	10$\bar{1}$	11$\bar{2}$0	Common: small and frequently much curved: in the latter case images are spread out and often lie an appreciable distance from the theoretical position.

[1] These values are taken from the author's paper, loc. cit.
[2] Min. Mag., 1899, vol. xii, pp. 175–182.

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w	113	$0\bar{2}25$	Common, but small: often accompanied by vicinal planes: images poor.
v	229	0·7·7·18	Rare and minute: images very faint.
u	115	$04\bar{4}7$	Rare and minute: images poor.
l	$31\bar{3}$	$24\bar{6}1$	Rare and minute: images poor.

The terms used to indicate the size of the faces must, of course, be interpretated relatively to the size of the crystals.

In Table II are compared the calculated values and the means of the observed azimuths and distances corresponding to the various forms, *r* being the reference-pole; the angles employed as the basis for the calculations are indicated by the asterisks. In Table III are given the calculated values, *c* being the reference-pole, together with the mean angles observed on the six crystals measured from this pole.

Table II.

Measurements from $r = (100) = (10\bar{1}1)$.

Form.	Indices.		Calculated Values.		Observed Means.		Number.	Limits of Observations.	
	Rhombohedral.	Hexagonal.	Azimuth.	Distance.	Azimuth.	Distance.		Azimuth.	Distance.
a	$01\bar{1}$	$\bar{1}2\bar{1}0$	*	*	90° 0′	90° 0′	26		90°20′
l	$13\bar{3}$	$26\bar{4}1$	,,	75°51½	,, ,,	75 56	5		75°42′– 76 15
f	$11\bar{1}$	$02\bar{2}1$	,,	52 55	,, ,,	52 57	69		52 29 – 53 15
l	$3\bar{3}1$	$64\bar{2}1$	60°48′	– 47 47	61 10	– 47 41	2	61 7′, 61°13′	47 36, 47 46
r	010	$\bar{1}101$	41 49	*	41 53½	82 49½	74	41 7 – 42 37	81 56 – 83 28
e	110	$01\bar{1}2$	,, ,,	41 25	,, ,,	41 24	37	,, ,, ,, ,,	41 8 – 41 51
a	$1\bar{1}0$	$2\bar{1}\bar{1}0$	,, ,,	– 48 35	,, ,,	– 48 27	33	,, ,, ,, ,,	48 5 – 48 56
u	151	$\bar{4}407$	30 49	71 17½	30 15	71 14	1		
w	181	$\bar{2}20\bar{5}$	24 6	65 10	24 22	65 23	16	23 45 – 24 57	64 39 – 66 0
l	$3\bar{3}1$	$62\bar{4}\bar{1}$	,, ,,	– 52 20	,, ,,	– 52 21	6	,, ,, – ,, ,,	51 30 – 52 56
e	$01\bar{1}$	$\bar{1}01\bar{2}$	*	80 25	0 0	80 30½	18		80 9 – 80 56
c	111	0001	,,	49 48	,, ,,	49 45	29		49 6 – 50 10
w	311	$20\bar{2}5$	,,	24 28	,, ,,	23 59½	14		23 11 – 24 39
v	922	7.0.7.18	,,	17 7½	,, ,,	17 24	3		17 7 – 17 45
u	511	$40\bar{4}7$	,,	15 44	,, ,,	15 48	5		14 54 – 16 6
f	$11\bar{1}$	$20\bar{2}1$	,,	– 63 6½	,, ,,	– 62 56½	41		62 25 – 63 41

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TABLE III.

Measurements from $c = (111) = (0001)$.

Rhombohedral; axis $c = 1{\cdot}0248$.

Form.	Indices.		Calculated Values.		Observed Means.		Number.	Limits of Observations.	
	Rhombohedral.	Hexagonal.	Azimuth.	Distance.	Azimuth.	Distance.		Azimuth.	Distance.
a	$\bar{1}01$	$\bar{1}120$	30° 0′	90° 0′	30° 0′	90° 0′	2	30°23′	90°
l	318	$\bar{4}261$	19 6½	80 56	19 7	80 55	2	19° 0′, 19 14	80°50′, 81
f	$\bar{1}11$	$\bar{2}021$	0 0	67 5½	0 0	67 12	24		66 30 – 67 5
e	011	$\bar{1}012$	,, ,,	30 37	,, ,,	30 41	17		29 45 – 31 4
w	311	2025	,, ,,	– 25 20	,, ,,	– 25 31	6		25 5 – 25 4
v	922	7.0.7.13	,, ,,	– 32 40½	,, ,,	– 32 42	6		32 15 – 33 1
u	511	40$\bar{4}$7	,, ,,	– 34 4	,, ,,	– 33 45	3		33 32 – 33 5
r	100	$10\bar{1}1$	,, ,,	– 49 48	,, ,,	– 49 42	17		49 0 – 50 1

Perhaps the most interesting point connected with these crystals is the fact that the optical characters displayed by them are not in accordance with the apparent morphological symmetry. Unless crushed to minute fragments they do not give extinction between crossed nicols, and there is no noticeable variation in the intensity of the transmitted light. A few crystals were crushed in oil, and occasional fragments were observed which are approximately perpendicular to one of the optic axes characterizing a biaxial crystal, and give in convergent light a biaxial brush. The precise relation of these microscopic fragments to the crystalline arrangement could not be ascertained, since it was not found possible to grind a section thin enough for the purpose.

As may be expected from what has just been stated, paratacamite is apparently singly refractive as far as regards light refracted across a prism. An approximate determination of the index gave the value 1·846 for the green light which is transmitted by the crystals; light of longer wave-length is almost entirely absorbed in transmission across the smallest crystal available for this purpose. The value obtained is very near the mean index of atacamite.[1]

[1] loc. cit., p. 24.

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Chemical Composition (G. T. P.).

Chemical analysis shows that the mineral is an hydrated oxychloride of copper having the same empirical formula as atacamite, viz.

$$CuCl_2.3Cu(OH)_2.$$

An analysis made on 0·5132 gram gave the following result:—

CuO	56·10
Cu	14·27
Cl	15·97
H_2O [1]	14·10
	100·44

The density (weight of 1 cc.) of the mineral is 3·74, as determined with a 3 cc. pyknometer on 0·7430 gram.

In the case of the oxychlorides of lead, paralaurionite and laurionite, which are also two minerals having the same percentage chemical composition [2], it was found that the latter mineral on ignition began to lose water at a lower temperature than the former. Experiment suggests that a similar relation subsists between paratacamite and atacamite. On heating at gradually increasing temperature up to 230° C. no change was produced in either mineral; but, after heating for about an hour at 250°, 0·0976 gram of atacamite began to blacken and lost about 2 mg. in weight, while paratacamite (0·1027 gram) still remained unchanged; continuing the heating for another hour at 260°, however, paratacamite just began to blacken and lost 0·5 mg., while atacamite lost an additional 2 mg. After heating for another hour at 280°, atacamite had lost altogether 5 mg. and paratacamite 4 mg.

Summary of Characters.

An hydrated oxychloride of copper, $CuCl_2.3Cu(OH)_2$. Pseudo-rhombohedral. Twins common, twin-plane *r*. Commonly in rhombohedra (*r*), or slender prismatic crystals elongated parallel to the edge of a zone [*rfa*]. Cleavage, *r* good. Fracture, conchoidal. Brittle. H. = 3, G. = 3·74. Lustre, vitreous. Colour, bright green, varying in shade according to the thickness. Streak, green. Refractive index, 1·846. Shows optical anomalies.

[1] From loss on ignition of a glass tube containing the mineral and a plug of dry sodium carbonate. A direct determination of the water made on 0·3464 gram by Penfield's method gave as low a percentage as 12·56, but there is reason to fear that some loss of water may have occurred.

[2] Min. Mag., 1899, vol. xii, p. 110.

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Phenacite and other minerals from German East Africa.

By L. J. Spencer, M.A., F.G.S.
Assistant in the Mineral Department of the British Museum.

[Read March 15, 1905.]

A SMALL collection of minerals, together with other natural history specimens, has recently been acquired by the British Museum from the Rev. A. North Wood, a missionary in the Usagara (Ussagara) province of German East Africa. Mr. Wood's station is situated at Itumba, and the specimens had been brought to him by the natives from the surrounding district, mainly from places between Mamboya and Mpapwa, which lie on the caravan route from the coast opposite Zanzibar westwards into the interior to Lake Tanganyika.

The rocks of the district are biotite-gneiss and hornblende-gneiss, the latter with small garnets[1].

Phenacite from Kisitwi Mountains[2].—A single isolated crystal[3] measuring about 1½ cm. in length by rather less than 1 cm. in diameter. It is perfectly colourless and transparent, and is bounded by numerous bright crystal-faces: it had been mounted as a pendant. It is a doubly terminated crystal, but at the end where it was attached to the matrix only a few faces are developed.

The following forms are present:—

Hexagonal prisms—

$a = \{10\bar{1}\} = \{11\bar{2}0\}$ $\quad m = \{2\bar{1}\bar{1}\} = \{10\bar{1}0\}$

Rhombohedra of the first order—

$r = \{100\} = \{10\bar{1}1\}$ $\quad z = \{22\bar{1}\} = \{01\bar{1}1\}$

$d = \{110\} = \{01\bar{1}2\}$ $\quad \mu = \{11\bar{1}\} = \{0221\}$

Rhombohedra of the second order—

$p = \{210\} = \{11\bar{2}3\}$ $\quad p_1 = \{201\} = \{2\bar{1}\bar{1}3\}$

Rhombohedra of the third order (hemi-scalenohedra)—

$s = \{20\bar{1}\} = \{21\bar{3}1\}$ $\quad s_1 = \{2\bar{1}0\} = \{3\bar{1}\bar{2}1\}$

$x = \{21\bar{1}\} = \{12\bar{3}2\}$ $\quad y_1 = \{42\bar{3}\} = \{65\bar{1}5\}$

[1] C. Dantz, Mitth. Deutschen Schutzgebieten, 1902, vol. xv, p. 52 (Abstract in Zeits. prakt. Geol., 1902, Jahrg. x, p. 306).

[2] The Kisitwi range extends between Rubeho and Mulale (or Mlali); there is also a small village of the same name.

[3] British Museum, No. 1905,115.

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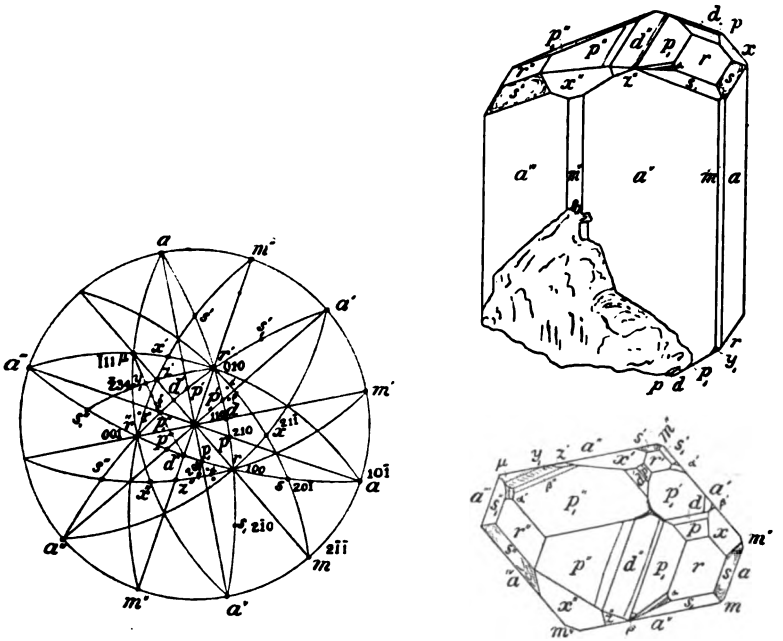
The form y_1 {423}, which is new for phenacite, is represented by two small and somewhat rounded faces, situated at opposite ends of the crystal and parallel to one another. The face in the position ($\bar{2}84$) was observed to lie in the zones $[d''\,p_1''] = [101, 012]$ and $[r'\,z'] = [010, \bar{1}22]$: it is inclined at 6° 16′ to z' and at 20° to p_1''. The form μ {11$\bar{1}$} is represented by only one face, which is very rough and reflects no image. z {22$\bar{1}$} has only two faces, one of which is quite small.



Phenacite from German East Africa.
(Stereographic projection, clinographic drawing, and plan[1].)

Two faces of the prism m are absent. All the other rhombohedra given in the above list are each represented on the top of the crystal by three well-developed faces. At the opposite, attached end of the crystal some of the parallel faces are present; but a face of s_1 is missing from an edge between r and a. Apart from these accidental omissions of faces, the crystal is clearly rhombohedral with parallel-faced hemihedrism, possessing only a triad axis and a centre of symmetry.

[1] The method of giving a plan of the crystal together with the clinographic drawing was employed by N. I. Koksharov, in 1853, in his 'Materialien zur Mineralogie Russlands' (compare this volume, p. 44).

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The faces of the complementary forms p and p_1 show little or no difference in surface characters, but, as may be seen from the figure, those of the latter are somewhat the larger in each of the three pairs. The faces of s and s_1 are equal in size and brightness; but whilst those of s_1 are even, those of s are rounded with platy layers of growth. There are no indications of the presence of the form complementary to x, though near by this position there are some irregular planes and rounded surfaces. The two complementary rhombohedra of phenacite have been distinguished by some authors according to whether they lie on the right-hand or on the left-hand side of r. Thus in the accompanying figures and projection x lies on the right of r; but it must be remembered that at the other end of the crystal x lies on the *left* of r.

Several good readings of the angles between the faces were obtained. Thus the angles over the six edges rp at the top of the crystals were determined as 20° 4′, 20° 6′, 20° 5′, 20° 5′, 20° 4½′, 20° 4′; and the three angles pp_1'' over the apex as 47° 38½′, 47° 38′, 47° 37½′. From the mean value $pp_1'' = 47° 38'$ is calculated $rp = 20° 5'$, agreeing with the mean of the measured angles. The corresponding angles given by Koksharov in 1857 for phenacite from the Urals, and adopted for the species in the textbooks, are 47° 34′ and 20° 4′. (Miller, in 1852, gave 47° 30′ and 20° 3′.)

The images reflected from the faces are often very good, though not always single. Portions of the two faces lettered d'' and p'' in the figures are replaced by smooth and well-defined vicinal faces, which give sharp images and lie accurately in the zone $[rr'']$. The vicinal face on d'' makes a salient angle of 56′ with this face; and that on p'' gives two images at 44½′ and 1° 0′ from the true position of p''.

Associated with the three faces of the form p_1 there are also three bright vicinal faces β, β', β'', which lie in the zones $[s_1\, d''\, p_1''\, y_1]$, &c., and are inclined to p_1 at about 3°: they are slightly rounded in these zones, the face in the position β'' being more rounded than the other two and giving a band of reflected light between 3° and 6° from p_1''.

Another set of small bright faces a, a', a'', somewhat similar to the last in character, replace the three corners $(r\, p_1\, s_1)$, &c. From each face of the form p_1 these faces form a banded zone; the angles measured for the more definite images in each being:

$p_1 a = 6° 43', 10° 21'$, and $12° 56'$.
$p_1' a' = 7° 24'$. $(r'a' = 14° 49'.)$
$p_1'' a'' = 6°$ and $13°$.

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The middle one of the three narrow faces at a, which gives the reading $p_1\ a = 10°\ 21'$, lies in the zone $[r z'']$ and makes with r an angle of $13°\ 9'$: it therefore has the indices $(7\bar{1}2) = (8\bar{3}5\bar{8})$. The indices of the zone $[p_1\ a]$ will then be $[13\bar{2}]$. The only other face on the crystal which should lie in this zone is μ $(\bar{1}11)$, but as this happens to be the only face which gives no reflected image this zonal relation could not be tested: some of the scattered and banded images reflected from the rounded surfaces on y_1 were, however, observed to lie in this zone.

Many of the edges between the faces of the crystal are perfectly sharp; but others, especially those between the prism and rhombohedron faces and those at the apex of the crystal, are rounded as if by corrosion. These rounded surfaces are quite bright, and reflect numerous scattered images. Some of the vicinal faces noted above are therefore probably of the nature of prerosion faces. They conform in their arrangement with the symmetry of the crystal.

The faces of the crystal are not marked with any definite etched figures. They are usually quite smooth and bright, but when examined closely many of them show duller and brighter areas with a patchy distribution.

The refractive indices for sodium light were determined as

$$\omega = 1{\cdot}653 \qquad \epsilon = 1{\cdot}672$$

but the images seen through the natural prism-faces being rather scattered, these results are only approximate. The specific gravity of the crystal is 2·8, this low value being readily accounted for by the numerous cavities. The crystal readily becomes electrified when rubbed.

The large number of cavities, some of them of considerable size, present in the crystal are of various shapes: (*a*) small and rounded; (*b*) lamellar, with surfaces parallel to the faces s and s_1, and bounded at the edges by small bright planes; (*c*) long and tubular, parallel to the triad axis of the crystal. Many of the cavities contain small black spots and globules of carbonaceous (?) material, and others contain brown films of iron oxide. A few contain a liquid with a bubble of gas, which disappear when the crystal is held in the warm hand; the liquid is therefore carbon dioxide.

Corundum from Mulale (eight miles west of Kisitwi).—Isolated crystals, 2–3 cm. in length, of a rose-red or flesh-red colour, and opaque or only slightly translucent. The predominating form is a steep hexagonal bipyramid $\nu\ \{1{\cdot}18{\cdot}\bar{1}1\} = \{44\bar{8}1\}$, with faces inclined to the basal plane at about 84°. Other forms present are the basal pinacoid $c = \{111\} = \{0001\}$, the rhombohedron $r = \{100\} = \{10\bar{1}1\}$, and the hexagonal

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bipyramid $n = \{13\bar{1}\} = \{22\bar{4}3\}$. Parting planes parallel to the rhombohedron r are sometimes present.

The faces of the crystals are curiously marked by a network of ridges, giving rise to a number of shallow pits with flat bottoms. These are probably the impressions of a granular aggregate of crystals in which the corundum crystals were originally embedded. In fact, there are attached to the surface of the crystals, or enclosed in them, several small grains or rounded crystals of a black, lustrous mineral, which proved on examination to be *rutile*.

Tourmaline from Kisitwi Mountains.—Isolated crystals measuring about 2 cm. across. They are jet-black and opaque, and have bright faces. One doubly terminated crystal is a short prism with the forms $a = \{10\bar{1}\} = \{11\bar{2}0\}$, $m = \{2\bar{1}\bar{1}\} = \{10\bar{1}0\}$, $r = \{100\} = \{10\bar{1}1\}$, and $c = \{111\} = \{0001\}$, the last being developed at one end only of the crystal. Another crystal shows at one end large smooth faces of $u = \{08\bar{2}\} = \{32\bar{5}1\}$ and $r = \{100\} = \{10\bar{1}1\}$; striated prism-faces are also present.

Tourmaline is also found in the Kiboriani Mountains.

Amethyst from Midindo (between Mamboya and Kitangi).—Small (1–2 cm. across), isolated bipyramidal crystals with prism-faces. They are transparent and of fairly good colour; the colour varies, however, in intensity, and in places the crystals are colourless. Numerous needles (of göthite ?) are enclosed in the crystals.

Albite from the Itumba district.—An isolated crystal measuring $3 \times 2 \times 1\frac{1}{2}$ cm. It is white and only slightly translucent, and is bounded on all sides by crystal-faces belonging to the forms c {001}, b {010}, m {110}, M {1$\bar{1}$0}, e {021}, n {02$\bar{1}$}, p {1$\bar{1}$1}, o {11$\bar{1}$}, x {$\bar{1}$01}, y {$\bar{2}$01}. All the faces, except b, are striated by repeated twinning on the albite-law. The cleavage-angle bc was measured as 86° 15′, and the angle between two c cleavages across a plane of twinning as $7\frac{1}{4}$°. The angles of optical extinction on c and b are 4° and 16° respectively with reference to the edge b/c. These determinations agree well with the constants recorded for albite, but the specific gravity of 2·55 is rather low, being less than that of orthoclase.

Orthoclase from the Itumba district.—A cleavage fragment measuring $3\frac{1}{2}$ cm. across and 1 cm. in thickness. It is milky-white and translucent, and has a pearly lustre on the basal (c) cleavage, thus somewhat resembling moon-stone in appearance. Under the microscope it shows a microperthitic structure, owing to the enclosure of spindle-shaped bodies parallel to the hemi-orthodome (80$\bar{1}$): the angle between the

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basal plane and (80$\bar{1}$) was measured under the microscope as 73°. The extinction angle on the plane of symmetry is +12° measured to the edge *c*/*b*; the plane of the optic axes is perpendicular to the plane of symmetry. The cleavage-angle *bc* was determined on the goniometer to be 90°. Specific gravity, 2·65.

Kaolin from Ikwamba (between Uponera and Kisitwi).—An incoherent mass of pure white material. Throughout the whole mass there is a minute lattice-like or cellular structure marked out by three sets of planes respectively parallel to the planes (010), (001), and (80$\bar{1}$) of orthoclase. The angle between (001) and (80$\bar{1}$) was determined to be about 73°, and the angles between these planes and (010) are 90°. The mass is thus the remains of a large crystal of orthoclase, in which the alteration to kaolin had taken place along the cleavage and parting planes.

Diopside from between Kisitwi and Mulale.—An aggregate of small indistinct crystals of a pale green colour.

Muscovite from Uluguru Mountains.—In addition to the species mentioned above, the collection also contains a sheet of mica from the Uluguru Mountains, in the Ukami province, and about 100 kilometres to the south-east of Itumba. Mr. Wood, however, states that mica is also found in the Itumba district.

The specimen is a trimmed sheet measuring 19 by 12 cm. It is transparent, with a slight smoky shade of colour, without flaws, and readily cleavable into very thin, elastic leaves. The optic axial angle (2E) is about 60°.

A detailed description of the occurrence of large sheets of mica in the pegmatite-veins traversing the gneiss of the Uluguru Mountains has been given by W. Bornhardt.[1] Sheets of commercial value have been exported from this locality.

[1] W. Bornhardt, 'Zur Oberflächengestaltung und Geologie Deutsch-Ostafrikas,' Berlin, 1900, p. 328 (abstract in Zeits. Kryst. Min., 1902, vol. xxxvi, p. 422; see also Zeits. prakt. Geol., 1908, Jahrg. xi, p. 199).

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Notes on some Binnenthal minerals (Ilmenite, Seligmannite, Marrite, &c.)

By R. H. Solly, M.A.

[Read November 14, 1905.]

Ilmenite.[1]

Some very brilliant and well-modified crystals of ilmenite, recently found in the neighbourhood of the Ofenhorn, are of interest in that they exhibit a well-marked parallel hemihedrism and show the presence of a number of new forms. Although constantly sought for, it is more than fifteen years since crystals of this mineral were last found in the Binnenthal. The crystals described by H. Bücking[2] in 1877 appear to differ in habit from those of the new find.

The crystals now described are attached to a matrix of mica-schist, and the associated minerals are quartz, adularia, magnetite, and mica. The plane (111) of the ilmenite is largely developed, and is finely striated parallel to its edges of intersection with the planes of the form $n = \{81\bar{1}\}$

[1] The crystal described above, and the specimen from which it was taken, have been acquired by the British Museum. The crystal was measured on the three-circle goniometer by Mr. G. F. Herbert Smith, and the following additional new forms were observed:—$q = \{331\} = \{\bar{6}241\}$, $k = \{\bar{4}52\} = \{3121\}$, $\Gamma = \{3\bar{1}\bar{1}\} = \{40\bar{4}1\}$, and $d = \{411\} = \{10\bar{1}2\}$. The faces were in all cases small, but gave distinct reflections of the collimator-slit. The measurements were made from the large basal plane $c = \{111\} = \{0001\}$, and the azimuths were determined from the nearest zone containing a pole of the form $a = \{10\bar{1}\} = \{11\bar{2}0\}$. The calculated values were computed from Koksharov's fundamental angle adopted in Dana's 'System of Mineralogy,' 6th edit., 1892.

[2] Zeits. Kryst. Min., 1877, vol. i, p. 576.

Form.	Indices.		Calculated Values.		Observed Means.		Number.	Limits of Observations.	
	Rhombohedral.	Hexagonal.	Azimuth.	Distance.	Azimuth.	Distance.		Azimuth.	Distance.
Γ	$3\bar{1}\bar{1}$	$40\bar{4}1$	30° 0′	81° 6½′	30° 0′	81° 5′	1		
d	411	$10\bar{1}2$	,, ,,	38 38	,, ,,	38 30	1		
q	331	$\bar{6}241$	10 53½	83 16	10 40	83 9	3	10° 34′–10° 45′	83° 4′–83° 13′
k	$\bar{4}52$	3121	,, ,,	76 42	,, ,,	76 41	2	,, ,, ,,	76 40, 76 42

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The forms present are the following, the six in the second column being new for ilmenite:—

$c = \{111\} = \{0001\}$	$a = \{992\} = \{0{\cdot}7{\cdot}7{\cdot}20\}$
$a = \{10\bar{1}\} = \{11\bar{2}0\}$	$X = \{51\bar{3}\} = \{44\bar{8}3\}$
$r = \{100\} = \{10\bar{1}1\}$	$\gamma = \{21\bar{1}\} = \{12\bar{3}2\}$
$s = \{11\bar{1}\} = \{02\bar{2}1\}$	$\delta = \{58\bar{1}\} = \{24\bar{6}7\}$
$n = \{31\bar{1}\} = \{22\bar{4}3\}$	$\beta = \{3{\cdot}8{\cdot}13\} = \{5{\cdot}5{\cdot}10{\cdot}24\}$
	$h = \{3\bar{1}2\} = \{41\bar{5}0\}$

The forms n, X, γ, δ, and β are hemihedral with parallel faces, being rhombohedra of the third order or hemi-scalenohedra. The faces X, n, and β lie in the zone $[ca]$, X and n being on one side of c and β on the other side. The face a lies between the faces c and s in the zone $[cr]$: γ lies between n and s, and δ is near to this in the zone $[c\delta\gamma]$. On the crystal (fig. 1) which was measured there are also some very small faces between c and n, and between c and s. The angles observed on this crystal are given below.

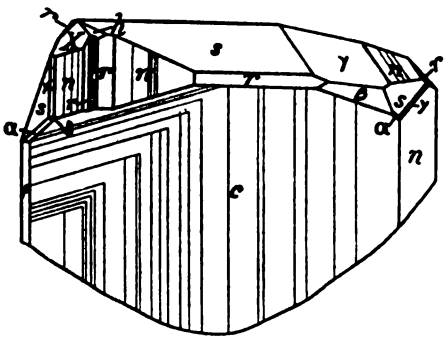

Fig. 1.—Ilmenite.

	Calculated.[1]	Measured.
$cr =$	$57°58\frac{1}{2}'$	57°58′, 57°59′, 57°58′.
$ca =$	29 14	29°12′, 29°10′, 29° (max. light).
$cs =$	72 38	72°38′, 72°38′, 72°38′.
$cc' =$	180 0	180°0′.
$cn =$	61 33	61°33′, 61°34′, 61°31′, 61°33′.
$cX =$	$74\ 50\frac{1}{2}$	74°50′, 74°51, 75° (max. light).
$ca =$	90 0	90° (max. light).
$c\beta =$	$29\ 58\frac{1}{2}$	30°0′, 29°59′, 29°57′, 30° (poor image).
$c\delta =$	$50\ 23\frac{1}{2}$	50°22′, 50°30′ (faint), 50° (max. light).
$c\gamma =$	$64\ 41\frac{1}{2}$	64°41′, 64°40′ (faint), 64°42′.

[1] Calculated from the element of N. I. Koksharov, 'Materialien zur Mineralogie Russlands,' 1870, vol. vi, p. 357.

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$as =$	84 15	84°16′, 84°18′.
$a\gamma =$	53 43	53°43′, 53°43′.
$an =$	63 55	63°55′, 63°55′.
$ar =$	90 0	90°0′, 90°0′.

Seligmannite.

Hitherto [1] only twinned crystals of this rare mineral have been discovered. In August, 1905, however, a large untwinned crystal was found in the Lengenbach quarry. It was met with as a single crystal in the iron-stained dolomite, which seldom carries any of the numerous sulph-arsenites. The crystal measures $10 \times 7 \times 5$ mm., and its actual shape is represented in fig. 2. Owing to the absence of twinning and of cleavage, it appeared at first sight to be a large and highly modified crystal of tennantite ('binnite'), but when measured the angles were seen to be those of seligmannite.

The planes of the form {110} are largely developed. Those of the forms {131}, {121}, and {111} are finely striated parallel to their mutual intersections; and those of {031} are striated parallel to their intersection with {010}.

Forty-five forms are present on the crystal, of which twenty-two are new; the latter are distinguished by an asterisk in the following list of forms. Fifty-seven forms have now been observed on this mineral, but only twenty-five of these are met with on bournonite, which Professor Baumhauer has suggested to be isomorphous with seligmannite.

$a = \{100\}$	$*F = \{061\}$	$*V = \{12{\cdot}1{\cdot}2\}$	$s = \{212\}$
$b = \{010\}$	$\Sigma = \{031\}$	$*S = \{713\}$	$*N = \{323\}$
$c = \{001\}$	$n = \{011\}$	$*T = \{613\}$	$D = \{322\}$
	$\kappa = \{013\}$	$*P = \{611\}$	$\phi = \{113\}$
$i = \{130\}$		$*X = \{14{\cdot}3{\cdot}6\}$	$u = \{112\}$
$f = \{120\}$	$*G = \{601\}$	$*U = \{413\}$	$y = \{111\}$
$m = \{110\}$	$*H = \{703\}$	$*O = \{313\}$	$*M = \{233\}$
$*l = \{320\}$	$*I = \{201\}$	$*Y = \{312\}$	$\rho = \{121\}$
$e = \{210\}$	$o = \{101\}$	$C = \{311\}$	$*L = \{131\}$
$\eta = \{310\}$	$*h = \{203\}$	$*Q = \{733\}$	$*Z = \{261\}$
$A = \{410\}$	$x = \{102\}$	$v = \{211\}$	$*K = \{161\}$
$*E = \{610\}$	$\epsilon = \{103\}$	$*R = \{533\}$	

[1] H. Baumhauer, Sitz.-ber. Akad. Wiss. Berlin, 1901, p. 110; 1902, p. 611. R. H. Solly, Min. Mag., 1903, vol. xiii, p. 336; 1905, vol. xiv, p. 82.

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The following angles were measured on this crystal:—

	Calculated.	Measured.
Zone [100,010].		
100 : 610	8°45′	9° ′
: 410	13 0	13 5
: 310	17 6½	17 10
: 210	24 47	24 48
: 320	31 37	31 37
: 110	42 43	42 43½
: 120	61 34	61 40
: 130	70 9	70 9½
: 010	90 0	90 0
Zone [100,001].		
100 : 601	9 59½	10
: 703	24 22½	24 30
: 201	27 51½	27 51
: 101	46 35½	46 35
: 203	57 46	57 50
: 102	64 41½	64 45
: 103	72 30	72 31
: 001	90 0	90 0
Zone [010,001].		
010 : 061	10 48	11
: 031	20 53½	20 52
: 011	48 52	48 52
: 013	73 46	73 46
: 001	90 0	90 0
Zone [100,013].		
100 : 713	25 16½	25
: 613	28 51	29
: 413	39 34	39 30
: 313	47 46	47 45
: 113	73 10	73 10
: 013	90 0	90 0

	Calculated.	Measured.
Zone [100,012].		
100 : 12.1.2	10°53′	11° ′
: 14.3.6	26 18½	27
: 312	37 34	38
: 212	49 5	49 2
: 112	66 34	66 35
: 012	90 0	—
Zone [100,011].		
100 : 611	18 10½	18
: 311	25 4½	25 4
: 733	31 2	31
: 211	35 3½	35 3
: 533	40 6	40
: 322	43 6	43 6
: 111	54 32	54 33
: 011	90 0	90 0
Zone [010,101].		
010 : 161	14 43	14
: 131	27 43	28 1
: 121	38 14½	38 14
: 111	57 36½	57 37
: 233	67 4½	67 8
: 212	72 24	72 21
: 313	78 3½	78 4
: 101	90 0	90 0

(233) lies in zones [121,112], [011,111]; (261) in zones [130,131], [010,211]; and (161) in zones [130,031], [010,131].

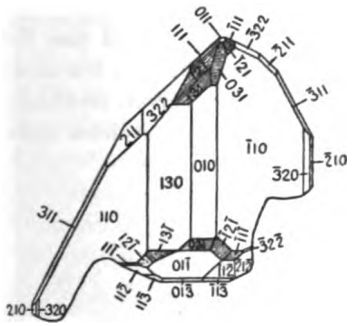

Fig. 2.—Seligmannite.

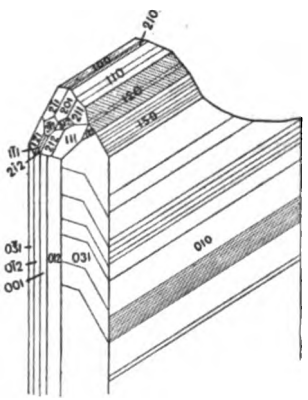

Fig. 3.—Marrite.

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Marrite.

During the summer of 1905 I came across only two crystals of this very rare mineral, of which there is still insufficient material for a chemical analysis. The two new crystals differ in habit from those previously described (this vol. p. 76).

Crystal No. 1 (fig. 3) was deposited in a cavity of the white dolomite, and in appearance closely resembles a tabular crystal of dufrenoysite. The faces in the zone [100,010] are deeply striated parallel to their mutual intersections; the face (031) is largely developed and is marked with obliquely placed striations.

Crystal No. 2, with a sharply pointed oblique habit, was deposited in the centre of a large hollow crystal of rathite. On this crystal the forms {170}, {150}, {140}, {031}, and {088} are largely developed.

The following list of thirty-four forms observed on the two crystals includes seven which are new.

$a = \{100\}$	$7r = \{170\}$	$*4k = \{041\}$	$-p = \{111\}$	$+p = \{11\bar{1}$
$b = \{010\}$.	$5r = \{150\}$	$\frac{7}{2}k = \{072\}$	$-2t = \{212\}$	$+2q = \{12\bar{1}$
$c = \{001\}$	$4r = \{140\}$	$3k = \{031\}$	$-2u = \{211\}$	
	$3r = \{130\}$	$*\frac{8}{3}k = \{083\}$	$-2q = \{121\}$	
$-2h = \{201\}$	$2r = \{120\}$	$\frac{7}{3}k = \{073\}$	$*-3q = \{131\}$	
$+2h = \{20\bar{1}\}$	$r = \{110\}$	$2k = \{021\}$	$*-5q = \{151\}$	
$+h = \{10\bar{1}\}$	$\frac{3}{2}s = \{320\}$	$k = \{011\}$	$*-w = \{271\}$	
	$2s = \{210\}$	$\frac{2}{3}k = \{023\}$	$*-v = \{312\}$	
	$*3s = \{310\}$	$\frac{1}{2}k = \{012\}$		

The plane 312 is well developed and lies in the zones [201,111] and [212,100].

In the following list of measured angles it will be noticed that the angles measured in the zone [010,201] differ somewhat from the calculated values. The same difference was observed in a crystal previously measured, and it would seem that the elements have not been quite correctly chosen.

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	Calculated.	Measured. I.	Measured. II.
Zone [100,001].			
(100) : (201)	30° 58′	30° 57′	—
: (001)	88 45	88 46	—
(100) : (20$\bar{1}$)	31 38	31 37	—
Zone [010,001].			
(010) : (041)	32 53	22 45	—
: (072)	21 5½	31 3	31° 3′
: (031)	35 8	35 6	35 8
: (083)	38 22	—	38 21
: (073)	42 8	—	42 30
: (021)	46 32½	46 22	46 28
: (011)	64 39	—	64 30
: (023)	72 28½	73	—
: (012)	76 40½	76 48	—
: (001)	90 0	90	—
Zone [010,201].			
(010) : (271)	31 10½	30 13	—
: (211)	76 43	76 17	—
: (201)	90 0	90 0	—

	Calculated.	Measured. I.	Measured. II.
Zone [010,100].			
(010) : (170)	13°55½′	—	13°59′
: (150)	19 8½	19° 8′	19 13
: (140)	23 27	23 30	23 27
: (130)	30 3	30 3	30 5
: (120)	40 57	41 0	40 53
: (110)	60 3	60 5	60 2
: (320)	68 59	69 1	—
: (210)	73 55½	73 50	—
: (310)	79 8	79 2	—
: (100)	90 0	90	—
Zone [010,101].			
(010) : (151)	28 55	28 53	—
: (131)	42 38½	42 38	—
: (121)	54 5½	54 6	—
: (111)	70 6	70 7	—
: (212)	79 44½	79 46	—
Zone [010,10$\bar{1}$].			
(010) : (12$\bar{1}$)	53 30	—	53 25
: (11$\bar{1}$)	69 42	—	69 45
: (10$\bar{1}$)	90 0	—	90

PROUSTITE.

This mineral has not hitherto been recorded from the Binnenthal. A single, minute crystal was found attached to a crystal of rathite[1], which was taken in 1905 from the white crystalline dolomite of the Lengenbach quarry. The crystal is a hexagonal prism a {10$\bar{1}$} terminated by the rhombohedron r {100}. The prism-angle was measured as 60° 0′, and the angles between the prism and rhombohedral faces as 53° 57′ and 53° 58′ (from the element given by Miers, $ar = 53° 54′$). The crystals of the two minerals are so arranged with respect to each other that the prism-edges are parallel.

TRECHMANNITE.

During the season 1905 very few crystals of the new red minerals described in the last number of this Magazine have been found in the Lengenbach quarry. One crystal, which was at first thought to be hutchinsonite, proved on measurement to be the very rare mineral trechmannite. It was found attached to a crystal of tennantite ('binnite'). The crystal is very irregularly developed; it shows the forms a {10$\bar{1}$}, m {2$\bar{1}\bar{1}$}, r {100}, and $x = a$ {21$\bar{2}$}. The faces of $x = a$ {21$\bar{2}$} ar-

[1] The rathite crystal is similar to that represented in fig. 5, Min. Mag., 1901, vol. xiii, Plate III.

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large and belong to a trigonal trapezohedron. This trapezohedral-hemihedral type of symmetry of trechmannite (like that of quartz and cinnabar) had already been noticed by Mr. G. F. Herbert Smith on the crystals previously described by me (this vol. p. 75).

Hyalophane and Barytes.

Some of the hyalophane crystals found during 1905 in the Lengenbach quarry are of a pale green colour, and had been mistaken for green tourmaline. Pale green crystals of barytes have also been found. At this locality the crystals of barytes are usually colourless, though sometimes bluish-grey in colour.

Montreux Club,
Territet, Switzerland.

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On the method of minimum deviation for the determination of refractive indices.

With a diagram (Plate IV).

By G. F. Herbert Smith, M.A., F.G.S.
Assistant in the Mineral Department of the British Museum.

[Read January 28, 1906.]

A DETERMINATION of the refractive power, which need be accurate to the second place of decimals only, is of considerable service for the discrimination of transparent substances, such as, in particular, faceted gem-stones. If the substance be so highly refractive that a total-reflectometer be not available, the method of minimum deviation is the simplest that can be used. Although the well-known formula

$$\mu = \frac{\sin\frac{A+D}{2}}{\sin\frac{A}{2}},$$

where A is the angle of the prism, D the minimum deviation, and μ the index of refraction, is only strictly true when the plane bisecting the prism-angle is one of symmetry with regard to the optical indicatrix, yet the value so given is sufficiently correct for the purpose. It is the large errors which have to be avoided. When there are many faces in the same zone, the incident and emergent faces corresponding to the refracted image under observation are not easily identified, and mistakes may be made in the arithmetical computation even though the formula given above is so simple. Any process or device, therefore, which will add to the certainty of arriving at a correct result may be of service.

In the form of goniometer which is employed for this work, the telescope and graduated scale can rotate independently about the same axis. The procedure should be as follows:—The telescope is clamped in the position directly opposite to the collimator, and the scale rotated until it reads zero. The latter is now clamped and the telescope turned in the direction of increasing readings until it reaches the position of minimum deviation for some refracted image; the corresponding reading of the scale gives at once the angle D required. The stone and scale both remaining fixed, the telescope is turned to the position in which

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the image reflected from the face of incidence is bisected by the cross-wires. This face should, if possible, always be one readily recognized, for instance the table facet of a cut stone; but in any case there should be little difficulty in identifying the face, since, if the telescope be rotated so that the images from consecutive faces are brought on to the cross-wires, it turns through double the angle between the faces in question, and therefore only one face will as a rule lie anywhere near a possible position. The telescope is in its turn clamped and the scale is read. The latter with the stone is rotated until the reading is that found for D. There should be in this position an image reflected from the face of emergence. The coincidence may not be exact because at minimum deviation a comparatively large rotation of the stone has no apparent effect on the position of the refracted image, apart from the fact that the formula already mentioned is not in general quite true. The difference between the last two readings gives the supplement of A. If this method be followed there will be no difficulty in correctly identifying the faces of the prism.

When the telescope is in the position for receiving the image reflected from the face of incidence the reading of the scale is theoretically $180°+A+D$. When the scale is rotated so that the image reflected from the face of emergence is on the cross-wires the reading is increased by $180°-A$, and thus we have $360°+D$ or D. Had the angle of minimum deviation been determined in the negative direction so that the reading of the scale was $360°-D$, we should have had instead $180°-(A+D)$ less $(180°-A)$ or $-D$, i. e. $360°-D$. The rule thus still holds good that the reading for the face of emergence is that previously found for the position of minimum deviation; and it remains true in the more general case, when the direct reading of the object-slit is any arbitrary angle and not zero.

In order to minimize the risk of errors in the computation, the author has prepared the diagram given on Plate IV. It is really a graphical interpretation of the formula

$$\mu = \frac{\sin\frac{A+D}{2}}{\sin\frac{A}{2}}$$

put into the form $\quad r = a\cos\theta + a\sin\theta\cot\frac{A}{2}$,

where $\quad \frac{r}{a} = \mu$ and $\theta = \frac{1}{2}D$.

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This may also be written in Cartesian co-ordinates

$$x^2+y^2 = ax+ay\cot\frac{A}{2},$$

whence we see that the formula thus expressed represents a family of circles, which pass through the origin and cut the axis of X at a distance a from the origin, and whose centres lie on the line $x = \frac{1}{2}a$. The family of circles are the curves running skew-wise across the diagram and have been drawn for every degree from $A = 10°$ to $A = 80°$. The radial lines are also drawn for every degree from $D = 10°$ to $D = 60°$. It may be noticed that the refractive index corresponding to any observed prism-angle and angle of minimum deviation within the given limits may be read off directly from the diagram to at least the second place of decimals. The range of the diagram includes refractive indices lying between 1·40 and 2·50.

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NOTES.

The following deaths have to be recorded:—

Emil Wilhelm Cohen (1842–1905), since 1885 Professor of Mineralogy in the University of Greifswald; previously (1878–85) he was Extraordinary-Professor of Petrology at Strassburg. He was the author of numerous papers on meteoric irons, and his 'Meteoritenkunde', of which three parts were published between 1894 and 1905, unfortunately remains incomplete. He visited South Africa in 1872, and was the first to give a detailed scientific account of the diamond-fields; many of his early petrographical and mineralogical papers are descriptive of material from this region. He also published a large series of photographic illustrations of rock-sections and of meteorites. A detailed biographical notice, together with a list of his published works, is given by Professor W. Deecke, his successor at Greifswald, in the 'Centralblatt für Mineralogie, &c.' (1905, pp. 513–530).

Per Theodor Cleve (1840–1905), since 1874 Professor of Chemistry in the University of Upsala. He was distinguished as a chemist, especially in connexion with his researches on the rare earths, but was also a recognized authority on microscopic marine organisms and hydrography. He analysed and described several mineral species, and the mineral cleveite was named after him in 1878.

Jean Baptiste Henry Dufet (1848–1905), since 1885 Professor of Mineralogy in the École Normale Supérieure at Paris. He made numerous exact determinations of the physical constants of crystals, especially of the optical constants of isomorphous mixtures. A biographical notice, with portrait and list of published works, is given by Professor G. Wyrouboff (Bull. Soc. franç. Min., 1905, vol. xxviii, pp. 246–258).

A new and revised edition has appeared (1905) of Professor A. H. Church's well-known Handbook of Precious Stones, which first appeared in 1882 and has several times been reissued; it has now been enlarged from 112 to 140 pages. The coloured plate has been redrawn, new diagrams being given of the absorption spectra of almandine and zircon. In his preface the author points out that the value of the precious stones exported from Ceylon is usually very much under-estimated and con-

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sidered of less importance than the graphite and pearls; as a moderate estimate he gives £800,000 as the value of the gem-stones (apart from pearls) annually exported.

New editions, in each case the fourth, have recently appeared of the following standard works: Professor P. Groth's 'Physikalische Krystallographie' (1905) has been increased by forty pages, there now being 820 pages as compared with 527 pages in the first edition of 1876. The principal alterations are in the optical portion. A distinction is now made between bivectorial and vectorial (e.g. pyro-electric) characters; and amongst the former a further distinction is made between physical characters of higher symmetry expressible by an ellipsoid (optical, electric, &c.) and those of lower symmetry (cohesion and elasticity).

The first volume, dealing with rock-forming minerals, of Professor H. Rosenbusch's 'Mikroskopische Physiographie der Mineralien und Gesteine' has now been split into two parts. The first part (1904) has been entirely rewritten by Professor E. A. Wülfing, and gives an excellent summary of the methods of investigation; while the second part (1905), descriptive of the rock-forming minerals, has been extensively revised and added to by Professor Rosenbusch himself.

New editions have also been issued of the textbooks of Mineralogy by Professor G. Tschermak (6th edit., 1905) and Professor Max Bauer (2nd edit., 1904).

An excellent volume on topographical mineralogy is the 'Mineralogia Groenlandica', by O. B. Boeggild, issued as No. 6 of the Contributions to Mineralogy from the Mineralogical and Geological Museum of the University of Copenhagen (Copenhagen, 1905, pp. xix + 625, with map). Being based on the rich collections of Greenland minerals, which have been gradually accumulated in the Copenhagen Museum during more than a century, the work contains much information not previously published: for instance, of the 119 figures of crystals 87 are new. The number of mineral species recorded with certainty is 162. The locality lists include both the new and the old spellings of place-names, and a map adds considerably to the usefulness of the volume. In the preface, which is written in English (the main part of the volume being in Danish), Professor N. V. Ussing gives some historical notes respecting the Copenhagen collections and the many collecting expeditions to

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Greenland. Mineral specimens were early brought home by the Danish missionaries, but the first systematic collections were those made by C. L. Giesecke in 1806–1813, while more recent is the remarkably rich material collected by G. Flink in 1897.

A new journal entitled 'Economic Geology', published bimonthly at Lancaster in Pennsylvania, is devoted to mining geology and the systematic study of ore-deposits. In scope it is very much the same as the 'Zeitschrift für praktische Geologie'. The first two numbers, issued at the end of 1905, include several original papers by well-known American geologists, together with personal notes, abstracts, and reviews. Commencing with 1906, the 'American Geologist' will be incorporated with the new journal, and its final number will contain a general index to the thirty-six volumes which have been published during the last eighteen years (1888–1905).

The Mines Branch of the Canadian Department of the Interior has commenced the issue of a series of publications on the economic minerals of Canada. The two monographs which have already appeared (1905) deal with mica and asbestos (i.e. chrysotile), and are by Fritz Cirkel. These extend to 148 and 169 pages respectively, and are illustrated by numerous figures, plates, and maps. They give a description of the general characters, modes of occurrence, methods of mining, and working of the minerals. Much of the information is of a strictly practical character, and in places shows evidence of having been hurriedly put together.

'Minerales alcalinos y terrosos de Colombia' and 'Gemas y minerales litoides de la Republica de Colombia' are the titles of two pamphlets, by R. Ll. Codazzi, recently issued as parts of the 'Trabajos de la Oficina de Historia Natural' (Bogata, 1904). A brief description is given of the characters of American species of minerals, with notes on their occurrence at North and South American localities, and in particular those of Colombia.

Other South American publications bearing on mineralogy have also reached us from Peru; namely, the 'Boletín del Cuerpo de Ingenieros de Minas del Perú', of which twenty-six numbers have already appeared (Lima, 1902 and 1905) and several more are promised. These deal primarily with the mineral resources of the different provinces, whilst

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others, for example No. 7 on 'El Cinabrio de Huancavelica', treat of a mineral of economic importance at a particular locality.

Although several artificial substances (tartaric acid, cane-sugar, &c.) are known to crystallize in the hemimorphic (sphenoidal) class of the monoclinic system, there is as yet no known example of this type of symmetry amongst minerals. Dr. H. Böckh ('Földtani Közlöny', Budapest, 1904, vol. xxxiv, p. 369) claims to have found an example in fichtelite, a hydrocarbon occurring in lignite. The crystals he describes exhibit the hemimorphic development of the faces and are pyro-electric, but they were artificially crystallized from a solution obtained by extracting a fichtelite-bearing lignite with ligroin, and can therefore scarcely be considered to be representative of a natural mineral.

The linear force exerted by growing crystals has been investigated by Drs. G. F. Becker and A. L. Day (Proc. Washington Acad. Sci., 1905, vol. vii, pp. 283–288). A weighted plate of glass was placed over a crystal of alum growing from solution, and it was found that a crystal 1 cm. in diameter could raise a kilogram weight through a distance of several tenths of a millimetre. The crystals grow with a cupped surface, and only a very narrow ring of material is in contact with the glass. The actual area of contact it was impossible to estimate, but it is so small that the force exerted by the growing crystal must amount to many pounds per square inch, being of the same order of magnitude as the resistance which the crystal offers to crushing stresses.

Attention is drawn to the geological importance of this force of crystallization, especially in connexion with the formation of quartz-veins and ore-deposits. If in quartz the force exerted during crystallization on the walls of the vein is comparable with the resistance which the material offers to crushing, then it must be considerable.

The so-called 'pine-apple' pseudomorphs, from the opal mines of White Cliffs in New South Wales, consist of precious opal with the form of acute four-sided pyramids of considerable size and arranged in radiating clusters. They have been examined by Jaquet, Weisbach, and Pelikan, who have variously suggested gypsum or sulphur for the original mineral, while Gürich compared them with the 'barley-corn' pseudomorphs of Sangerhausen. Recently Messrs. C. Anderson and H. S. Jevons

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(Records of the Australian Museum, 1905, vol. vi, pp. 31–37, two plates) have measured the angles between the somewhat rounded faces and find that the form is monoclinic; they also observed traces of a distinct cleavage perpendicular to the plane of symmetry. The angles approach those of glauberite ($Na_2SO_4.CaSO_4$), and this, the authors conclude, was the original mineral of these pseudomorphs.

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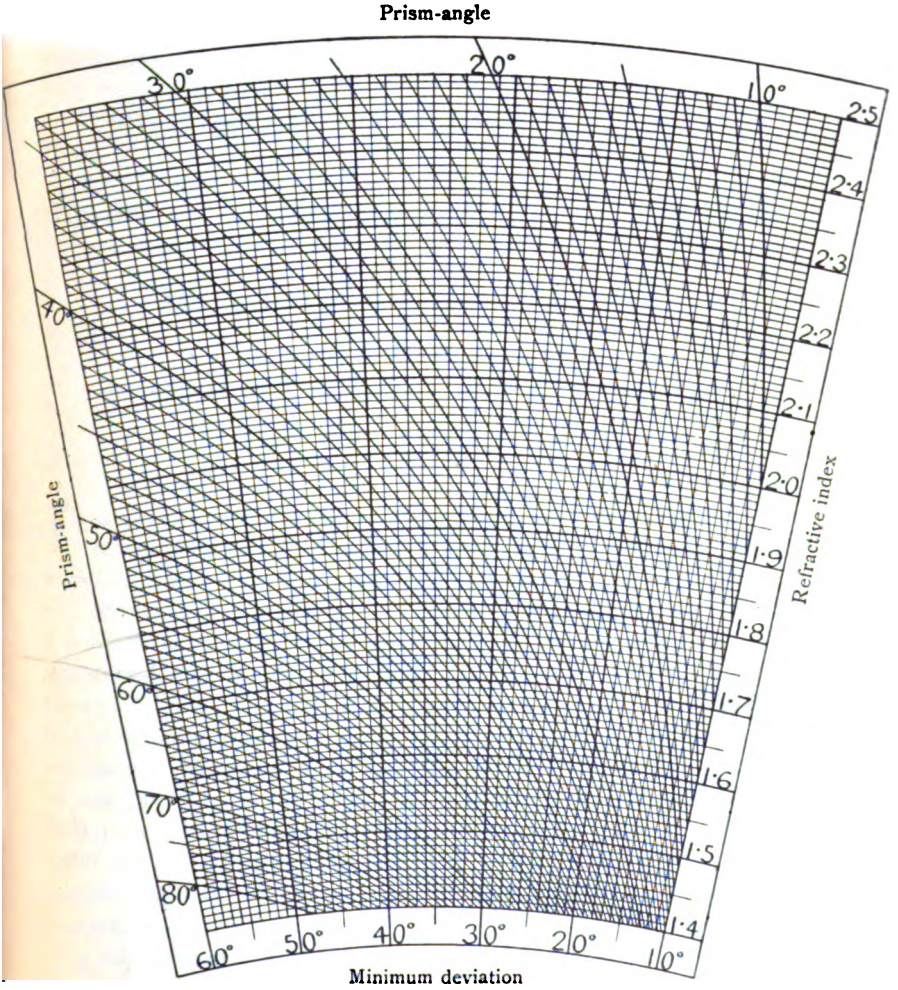

G. F. HERBERT SMITH : REFRACTIVE INDEX DIAGRAM.

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THE MINERALOGICAL MAGAZINE

AND

JOURNAL OF

THE MINERALOGICAL SOCIETY.

No. 66. February, 1907. Vol. XIV.

The optical characters of Antimonite.

By A. HUTCHINSON, M.A., Ph.D.

Demonstrator of Mineralogy in the University of Cambridge.

[Preliminary note read March 22, 1904.]

IN a paper communicated to this Society in March, 1903[1], it was shown that antimonite is fairly transparent to radiations of long wave-length and that its behaviour between crossed nicols is consistent with orthorhombic symmetry. At the same time it was pointed out that it would be of interest to determine the wave-lengths of the radiations transmitted and the principal indices of refraction of antimonite for these radiations. On undertaking this investigation it was soon found that antimonite was quite sufficiently transparent to the rays at the extreme red end of the visible spectrum to enable visual observations to be made, and in a verbal communication to the Society on March 22, 1904, it was stated that the indices of refraction for red light were 4·129 for rays vibrating parallel to the axis Z and 3·873 for rays vibrating parallel to the axis X. These numbers were based on measurements made on a prism the faces of which were very indifferent. They can therefore only be regarded as rough approximations. Further, the exact wave-length of the radiation transmitted was unknown, an omission of some importance, as a few measurements made with a thermopile in the infra-red indicated that the dispersion in this region was very great. These preliminary results were, however, of sufficient

[1] Min. Mag., vol. xiii, p. 312.

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interest to warrant an attempt to carry out a complete determination of the optical constants of antimonite with all the accuracy possible, and this investigation, though not quite finished, has now reached a stage when it seems desirable to put on record the results so far obtained.

The visible radiations transmitted by antimonite.—The first point to be determined was the wave-length of the visible radiations transmitted by antimonite. To effect this, one of Thorp's replicas of a Rowland grating having 14,504 lines to the inch was mounted on a spectrometer. Sunlight reflected from the silver surface of a heliostat mirror was focused on the slit by a quartz lens of 7 cm. diameter and 86 cm. focal length and the telescope was set on the line A of the solar spectrum. The slit was then entirely covered with a very thin cleavage-flake of antimonite. On now looking through the telescope it was found that the A line could still be distinctly seen, but that the more refrangible end of the spectrum was absolutely cut off just beyond A, while a considerable extension of the spectrum towards the infra-red had become visible. The antimonite was thus acting as one of the screens recently described by M. Štefánik[1], which have enabled him to see as far down the infra-red as ρ, σ and τ, and even under favourable circumstances to Φ, wave-length 1135.

On making these observations in a dark room, a faint line was observed in the region below A and by measurement was identified with Z of the infra-red solar spectrum, wave-length 823. The visible spectrum seen under these conditions extends somewhat beyond Z, but the illumination is too faint to permit of the identification of any more lines. It was thus established that a thin plate of antimonite transmits visible radiations extending from about 750 to about 850, and that in this region A and Z can be identified and used as standards.

Indices of refraction.—The principal indices of refraction were determined by the aid of two prisms prepared from a fine crystal of Japanese antimonite by Adam Hilger, Ltd.[2]

Prism I.—This prism was cut with its refracting edge parallel to the long axis, *Z*, of the crystal. One face was parallel to the cleavage-plane *b* (010), the other inclined to it at an angle of 7° 41′. Both faces had a very good polish and were sufficiently plane except quite close to the

[1] Compt. rend. Acad. Sci. Paris, 1905, vol. cxli, p. 585; 1906, cxlii, p. 986; cxliii, pp. 573 and 734.

[2] I desire here to record my appreciation of the great care and skill shown by the firm in working a very troublesome substance.

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thin edge. One face gave a sharp reflected image of the slit, that afforded by the other was less satisfactory. When the prism was placed on the spectrometer and sunlight condensed on the slit by the above mentioned lens, two broad red images of the slit were seen in the telescope. These images were plane polarized, the vibrations in the most deviated image being parallel to the refracting edge of the prism, i. e. to the axis *Z* of the crystal. The lines A and Z could be detected in both spectra, though they were not very distinct. The prism was adjusted so that the cleavage-face was perpendicular to the axis of the collimator. In this position the light is incident perpendicular to a principal plane, and the values of two of the principal indices of refraction can be deduced from the relation $\mu = \frac{\sin (P + D)}{\sin P}$, where P is the angle of the prism and D the deviation observed.

The mean values of the deviations were, for the line A 27° 26′ and 25° 4′ respectively, and for the line Z 26° 25′ and 24° 3′. Whence follow the values:—

μ_γ for line A = 4·303; for line Z = 4·193. Vibrations parallel axis *Z*.
μ_β „ = 4·046; „ = 3·919. „ „ „ *Y*.

Prism II.—The refracting edge of this prism was parallel to the cleavage and to the *X* axis of the crystal. One face of the prism was perpendicular to *c* (001) and therefore perpendicular to the cleavage, the second was inclined to the first at an angle of 9° 15′. Great difficulty was experienced in polishing the faces of this prism, and it was found necessary to cement the face perpendicular to the cleavage on to a plate of glass. Placed on the spectrometer, two widely separated red patches were seen, but the definition was not sufficiently good to enable the line A to be detected, much less the line Z. The telescope was therefore set on what was judged to be the central brightest portion of each patch corresponding roughly to the region about midway between A and Z. The mean deviations observed were 21° 4½′ and 30° 40½′ respectively, whence follow as above:—

μ_α = 3·141. Vibrations parallel axis *Y*.
μ_β = 3·993. „ „ „ *Y*.

Discussion of results.—The main source of error in the above observations is the uncertainty of the value of the prism-angle, any small inaccuracy in this determination having a great influence on the calculated value of μ, when such acute-angled prisms have to be employed. Thus an error of 1′ in the value of the angle of prism 1

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alters the corresponding value of μ by 0·007. An error of the same magnitude in the determination of the deviation is less serious, changing the value of μ by 0·002. There is no particular difficulty in getting fair readings for the deviation of the line A, but, owing to its faintness, Z is much harder to observe. The nature of the reflections from the faces of prism I were such as to render the value of its angle uncertain by about 1′ of arc. The values of μ_β and μ_γ are therefore probably correct within $\pm$ 0·01. In the case of prism II the uncertainty is somewhat greater, and A and Z cannot be distinguished. A probable value of μ_α for the line A can, however, be deduced from the numbers quoted above on the assumption that the double refraction $\mu_\beta - \mu_\alpha$ is about the same for A as for the region midway between A and Z. Subtracting then 0·852 from 4·046 we get 3·194 as the value of μ_α for the line A.

The optical scheme of antimonite for red light of wave-length 760 is therefore as follows:—

Plane of the optic axis parallel to a (100). Acute bisectrix perpendicular to c (001). Double refraction strong, negative.

$\mu_\alpha = 3{\cdot}194$. $\mu_\beta = 4{\cdot}046$. $\mu_\gamma = 4{\cdot}303$. Whence $2V = 25° 45'$.

In addition to exhibiting very strong double refraction, antimonite is remarkable as showing an extraordinarily high degree of dispersion in the region under consideration. Thus for β we have $\mu_A - \mu_Z = 0{\cdot}127$ and for γ we have $\mu_A - \mu_Z = 0{\cdot}110$. Carvallo's[1] measurements enable us to compare this dispersion with that of calcite, for which he found $\mu_{ord.}$ (760) = 1·6501 and $\mu_{ord.}$ (832) = 1·6477; difference = 0·0024. Thus the difference of the refractive indices in the case of antimonite is more than fifty times as great as in that of calcite.

Further, these results are of special interest in so much as they supplement the work of E. C. Müller[2], who by a study of the constants of elliptic polarization of the light reflected from fresh cleavage-surfaces of antimonite was enabled to draw the dispersion curves for the region extending from G to C.

In view of the information already gained it seems desirable that the investigation should be extended as far as possible into the infra-red region. Further, there seems ground for believing that with the aid of the experience now acquired, it may be possible to prepare

[1] Compt. rend. Acad. Sci. Paris, 1898, vol. cxxvi, p. 950.
[2] Neues Jahrb. Min., 1903, Beil.-Bd. xvii, pp. 187–251.

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a prism cut across the cleavage with surfaces good enough to enable A and Z to be recognized.

Work in both these directions is now in progress, and it is hoped that it may be possible before long to communicate further results to the Society.

Mineralogical Museum,
Cambridge.
December 5, 1906.

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The chemical composition of Lengenbachite.

By A. Hutchinson, M.A., Ph.D.
Demonstrator of Mineralogy in the University of Cambridge.

[Read June 14, 1905.]

LENGENBACHITE is one of the interesting minerals which occur in the dolomite of the Binnenthal, and we owe our knowledge of it, as of many other new species, to the careful investigations conducted in recent years by Mr. R. H. Solly at that remarkable locality. The crystallographic and physical characters, so far as they have proved capable of determination, have been already described by Mr. Solly in the pages of this Magazine (vol. xiv, p. 78). The material which he kindly placed in my hands for chemical examination consisted of cleavage-plates, exhibiting brilliant metallic lustre, and of foliated aggregates of thin greyish-black crystals. Some of the crystals were partially covered with a thin, white incrustation readily removed by boiling dilute hydrochloric acid, a reagent which appeared to be without action on the lengenbachite. After removal of the incrustation, whose nature was not further examined, advantage was taken of the highly perfect cleavage to split the crystals into as thin flakes as possible, in order that minute crystals of iron-pyrites imbedded in the lengenbachite might be picked out. Although this operation was carried out with great care, it seems not unlikely that a little pyrites may have escaped detection and the small quantity of iron subsequently estimated may possibly have been derived from this source. The cleavage-plates were next reduced to fine powder in an agate mortar, a process rendered tedious by the toughness of the laminae, but which was found to be absolutely necessary in order to ensure successful decomposition by chlorine gas.

Specific Gravity.—A careful determination of the specific gravity made on 2·231 gram of the powder, afterwards used for analysis, gave the value 5·85 at 15·5°C. compared with water at 4°C.

Analysis.—For the purpose of quantitative analysis, the substance, which had been found to contain lead, silver, copper, arsenic, antimony, and sulphur, was placed in a porcelain boat and decomposed by a current of chlorine in a glass tube, which was gently heated towards the end

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of the reaction. The elements contained in the residue and in the distillate were separated and estimated by the usual methods, and during the course of the work a small quantity of iron was found. Sulphur was determined in two independent experiments and control estimations of the arsenic also obtained; owing to an accident, a duplicate determination of the antimony was unfortunately spoilt. The results are exhibited in columns I, II, and III of the table below:—

	I.	II.	III.	Mean.	Atomic ratios.			
Pb ...	57·89	—	—	57·89	0·2798			
Ag ...	5·64	—	—	5·64	0·0522	÷2	0·3274	1·761
Cu ...	2·36	—	—	2·36	0·0371			
Fe ...	0·17	—	—	0·17	0·0030			
As ...	(13·29)	13·41	13·52	13·46	0·1795		0·1859	1·000
Sb ...	0·77	—	—	0·77	0·0064			
S ...	—	19·35	19·32	19·33	0·6032		0·6032	3·244
				99·62				

The weights of material used in each of the above analyses were as follows:—analysis I, 0·8750 gram; analysis II, 0·8987 gram; analysis III, 1·2828 gram. The weight of the mixture of chlorides remaining in the porcelain boat after the decomposition by chlorine was finished amounted in analysis I to 0·7933 gram. This weighing affords some check on the accuracy of the subsequent work, for the weight of the mixture of chlorides which should be formed from 0·8750 gram of lengenbachite can be calculated on the assumption that the percentages of lead, silver, copper, and iron given in column I above are correct. On calculation this weight was found to be 0·7938 gram, an agreement which may be considered satisfactory.

Chemical Formula.—The interpretation of the analytical results, though not wholly devoid of difficulty, offers some points of interest. If we assume in the first place that the small quantity of antimony is replacing an equivalent amount of arsenic, and secondly that two atoms of silver or of copper can, in this mineral, play the part of one atom of lead, and if the iron be treated as an essential constituent, then we see from an inspection of the columns headed atomic ratios that Pb: As: S = 1·761 : 1 : 3·244 or 7 : 4 : 13, very nearly. The empirical formula of the mineral is therefore $Pb_7As_4S_{13}$ or, as it may also be written, $7PbS . 2As_2S_3$. Accepting this interpretation, we find that lengenbachite takes its place naturally in the long series of compounds of lead, arsenic, and sulphur, filling a gap between guitermanite and

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jordanite, just as liveingite, baumhauerite, and rathite find their places between sartorite and dufrenoysite.

$PbS . As_2S_3$, Sartorite	$2PbS . As_2S_3$, Dufrenoysite
$5PbS . 4As_2S_3$, Liveingite	$3PbS . As_2S_3$, Guitermanite
$4PbS . 3As_2S_3$, Baumhauerite	$7PbS . 2As_2S_3$, Lengenbachite
$3PbS . 2As_2S_3$, Rathite	$4PbS . As_2S_3$, Jordanite

Another possible interpretation must not, however, be lost sight of. It may be that the number of the lead atoms bears a fixed relation to the number of the atoms of silver and of copper, and a consideration of the ratios lends some support to this view. Thus, if we assume that the iron is present as pyrites, and omit FeS_2 from the calculation, we find that the ratios are as follows:—

$$Pb : (Ag, Cu) : As : S = 0{\cdot}2798 : 0{\cdot}0893 : 0{\cdot}1859 : 0{\cdot}5972$$
$$= 6{\cdot}02 : 1{\cdot}92 : 4 : 12{\cdot}85.$$

A result which leads to the formula

$$Pb_6(Ag, Cu)_2As_4S_{13} \text{ or } 6PbS . (Ag, Cu)_2S . 2As_2S_3.$$

That the ratio Pb : (Ag, Cu) approaches in this case very nearly to three to one is an interesting fact. Whether it is a mere coincidence or whether, on the other hand, it has deeper significance can only be satisfactorily determined when more material is available for analysis. In the meantime the formula

$$6PbS . (\tfrac{3}{5}Ag, \tfrac{2}{5}Cu)_2S . 2As_2S_3$$

has the merit of expressing the analytical results with tolerable exactitude, the corresponding percentage composition being as follows:—

Pb, 58·07; Ag, 6·03; Cu, 2·38; As, 14·03; S, 19·49.

Mineralogical Museum,
Cambridge.

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Note on 'Feather-ore': identity of 'Domingite' (='Warrenite') with Jamesonite.

By L. J. Spencer, M.A., F.G.S.

Assistant in the Mineral Department of the British Museum.

[Read March 22, 1904.]

THE formula $2PbS.Sb_2S_3$, given for jamesonite in all the textbooks, does not belong to jamesonite at all, but to the 'Federerz' ('feather-ore') from Wolfsberg in the Harz analysed by H. Rose in 1829, and for which the mineralogical names wolfsbergite (Huot, 1841) and plumosite (Haidinger, 1845) have been proposed. Rose's formula for the cleavable jamesonite from Cornwall was $3PbS.2Sb_2S_3$. In 1860 Rammelsberg[1] united these, together with heteromorphite, under the name jamesonite and with the formula $2PbS.Sb_2S_3$: this has since been followed in the textbooks, but, as will be pointed out below, it is very probable that there are here three distinct mineral species.

The original jamesonite formula, $3PbS.2Sb_2S_3$, thus came to be forgotten, and when it again appeared in the literature it was consequently assumed to represent a new species. In this way one of the sulphantimonites of lead from Colorado analysed by Mr. L. G. Eakins[2] in 1888 was named 'domingite' by Professor Groth[3] in 1889, and 'warrenite' by Eakins[4] himself in 1890. The latter name has been generally accepted, although 'domingite' is the earlier of the two.

Eakins's formula, $3(Pb,Fe)S.2Sb_2S_3$, was deduced from a single analysis, made on material described as occurring in matted, wool-like aggregates of acicular crystals, and known locally as 'mineral-wool'. The results of his analysis (I) are compared below with the mean (II) H. Rose's

[1] For fuller historical details see Min. Mag., 1899, vol. xii, p. 58.

[2] L. G. Eakins, 'Two sulphantimonites from Colorado.' Proc. Colorado Sci. Soc., 1888, vol. iii, pp. 73–76; Amer. Journ. Sci., 1888, ser. 3, vol. xxxvi, pp. 450–453. The second of these minerals, which was described as freieslebenite, has since been shown to be boulangerite.

[3] 'Tabell. Uebersicht d. Mineralien.' Braunschweig, 1889, 3rd edit., p. 30.

[4] Amer. Journ. Sci., 1890, ser. 3, vol. xxxix, p. 74; Bull. United States Geol. Survey, 1890, no. 60, p. 117.

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analyses of Cornish jamesonite and with Dr. G. T. Prior's analysis (III) of crystallized jamesonite from Bolivia [1].

	S.	Sb.	Pb.	Fe.	Cu.	Ag.	Mn.	Gangue.	Total.
I.	21·19	36·34	39·33	1·77	traces			0·52	99·15
II.	22·56	34·26	40·18	2·63	0·18	—	—	—	99·81
III.	20·52	34·53	41·18	2·76	0·26	0·01	—	—	99·26

In the absence of any determinable physical or crystallographic characters, this analysis is scarcely sufficient to define a mineral species, especially among the sulphantimonites of lead. There is no guarantee that the material analysed was all of one kind. Nevertheless, on comparing the analysis of 'domingite' with the few analyses that have been made of cleavable jamesonite, it will be seen that they agree sufficiently closely to suggest an identity.

A specimen (British Mus. no. 84697) of 'domingite', collected in 1899 by Mr. E. R. Warren at the original locality (Domingo mine, Elk Mountain mining district, Gunnison Co., Colorado), was obtained in that year, through Mr. W. F. Ferrier, for the British Museum. The matrix of this specimen, collected twelve years after the abandonment of the mine, does not, however, agree with that of the original specimens, also collected by Mr. Warren, and described by Mr. Eakins as 'a highly decomposed gangue rock of siliceous material mixed with some calcite'. In the British Museum specimen the felted aggregates of short and straight needles fill cavities in pink rhodochrosite; the latter encloses a few specks of tetrahedrite, iron-pyrites, and arsenopyrite, and in the cavities it is crystallized as curved rhombohedra.

Attempts were made to measure the very minute, striated needles on the goniometer, but without result. It was, however, determined that the needles are brittle and not flexible. For reasons stated below, this latter character indicates that the material must be referred to jamesonite.

'Domingite' is thus one of the black, metallic minerals, capillary in form, to which the name 'feather-ore' would be applied.

Previous to Rose's analysis of 1829, 'feather-ore' was referred to stibnite, later it was referred to plumosite, while at the present time it is included under jamesonite. As a matter of fact 'feather-ore' may be stibnite [2] or any of the several acicular (orthorhombic) sulphantim-

[1] An account of this will be given in the next number of this Magazine.

[2] E. Kaiser, 'Haarförmiger Antimonglanz aus Rheinland und Westfalen.' Zeits. Kryst. Min. 1896, vol. xxvii, pp. 49–51. I have also found several specimens of capillary stibnite amongst the jamesonites in the British Museum collection.

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onites of lead. Of 'feather-ores' containing lead, antimony, and sulphur there are, as indicated by external characters, at least two kinds, viz.:

(*a*) Flexible 'feather-ore'.
(*b*) Brittle 'feather-ore'.

The fine capillary crystals of the former may be bent double without breaking, and when released they spring back to their original position. This would scarcely be possible if they possessed a good cleavage perpendicular to their length, as does jamesonite. Because of this cleavage, brittle 'feather-ore' is no doubt in all cases identical with jamesonite.

On the other hand, flexible 'feather-ore' may be either zinckenite, plumosite, boulangerite, or meneghinite, but it seems impossible to distinguish between these when only capillary crystals are available. In the absence of any characteristic feature it would be impossible to collect material all of one kind for chemical analysis. There is nothing to show that these finely acicular aggregates are not mixtures of various sulphantimonites of lead, or of these with stibnite. Further, when the hairs are closely examined with a lens or under the microscope there may often be seen minute crystals of galena threaded on them like beads on a string. Analyses of such undeterminable material are useless, and can only lead to error. I have for several years been looking out for material suitable for detailed examination, but so far without success.

Zinckenite, boulangerite, and meneghinite appear to be well established as distinct mineral species, but the existence of plumosite ($2PbS.Sb_2S_3$) is based only on the chemical analyses of felted masses of capillary crystals. The published analyses of 'feather-ore' which agree approximately with this formula are quoted below :[1]—

	I.	II.	III.	IV.	V.	Calculated $2PbS.Sb_2S_3$.
S ...	19·72	18·40	19·25	20·49	19·84	... 19·68
Sb ...	31·04	30·19	29·24	27·72	28·53	... 29·55
Pb ...	46·87	47·68	49·31	48·38	49·74	... 50·77
Fe ...	1·30	0·26	—	3·47	0·53	—
Cu ...	—	1·11	2·00	—	—	—
Zn ...	0·08	1·09	0·21	—	—	—
	99·01	98·73	100·01	100·06	98·64	100·00

[1] Three analyses of 'Federerz' agreeing very closely with the above formula are also given by C. Guillemain, Inaug.-Diss., Breslau, 1898, pp. 21, 24.

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I. H. Rose, Ann. Phys. Chem. (Poggendorff), 1829, vol. xv, p. 471. 'Federerz' from Wolfsberg, Harz.

II. E. Bechi, quoted by Meneghini, Amer. Journ. Sci., 1852, ser. 2, vol. xiv, p. 60. Capillary; from Bottino, Tuscany.

III. Ditto. Acicular; same locality.

IV. E. Bořický[1], quoted by V. von Zepharovich, Sitz.-Ber. Akad. Wiss. Wien, 1867, vol. lvi, Abth. I, p. 37. Fine elastic needles described as 'boulangerite'; from Przibram, Bohemia.

V. G. Baumert, quoted by O. Luedecke, 'Die Minerale des Harzes,' Berlin, 1896, p. 127. Felty mass of very fine fibres; from Schwenda, Harz.

Flexible 'feather-ore' containing lead, antimony, and sulphur must therefore be removed from jamesonite, and in collections can only be placed in a natural history group to which the name plumosite may be conveniently applied, although specimens so placed are not necessarily the same as Rose's plumosite.

In a previous paper[2] I have pointed out that heteromorphite must also be removed from jamesonite. The former is monoclinic with pyramidal cleavages, whilst the latter is orthorhombic with a basal cleavage.

In conclusion, the several sulphantimonites of lead are tabulated below, but the formulae assigned to them can only be regarded as provisional. They fall into two dimorphous groups. Those of the orthorhombic group occur as acicular and capillary crystals or as fibrous masses, whilst those of the monoclinic group occur as short pyramidal and tabular crystals or as granular masses. The former usually contain a small percentage of iron, whilst the latter contain none.

Orthorhombic.[3]		Monoclinic.	
Zinckenite,	$PbS . Sb_2S_3$	Plagionite,	$5PbS . 4Sb_2S_3$
Jamesonite,[4]	$7(Pb, Fe)S . 4Sb_2S_3$	Heteromorphite,	$7PbS . 4Sb_2S_3$
Plumosite,	$2PbS . Sb_2S_3$	Semseyite,	$9PbS . 4Sb_2S_3$
Boulangerite,	$5PbS . 2Sb_2S_3$		
Meneghinite,	$4PbS . Sb_2S_3$		

[1] Bořický also analysed a massive, fibrous 'jamesonite' from Przibram, which gave results agreeing with this formula (loc. cit., p. 32).

[2] 'Plagionite, heteromorphite and semseyite as members of a natural group of minerals.' Min. Mag., 1899, vol. xii, pp. 55–68.

[3] 'Schulzite' ($5PbS . Sb_2S_3$) and 'plumbostibite' ($10PbS . 3Sb_2S_3$) may possibly also belong to this group, but not geocronite (= kilbrickenite) since this appears to be a double salt, $5PbS . Sb_2S_3 + 5PbS . As_2S_3$ (Min. Mag., 1902, vol. xii, p. 188).

[4] This formula is deduced from the analysis, quoted above, of crystallized jamesonite from Bolivia.

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Note on Gypsum crystals found lining a disused well at chemical works.

By C. J. Woodward, B.Sc., F.G.S.

[Read November 14, 1905.]

BEFORE the value of hydrochloric acid for chlorine manufacture was recognized by soda-crystal makers, it was a common practice to get rid of the unpleasant fumes in the cheapest and most convenient way possible. At Messrs. Chance's works at Oldbury, near Birmingham, this was done by turning the gases from the salt-cake furnaces into a culvert which ran through some portion of the works. The better to condense the fumes, it seems probable that a brook, which runs near the works, was diverted into the culvert, thus forming a rough condenser. Some thirty years or so ago, when alterations were being made at these works, a culvert of this description was unearthed and found to be lined with crystals of gypsum, which had formed on the brickwork. An old well, which was opened, was also studded with beautiful tufts of crystals. I am indebted to Mr. A. M. Chance for a handsome specimen with numerous attached crystals of gypsum, and also for some stereoscopic slides showing the well with the crystals *in situ*.

The crystals on this specimen are from 20 to 80 mm. in length. They are elongated in the direction of the vertical axis, and are slightly tabular owing to the predominance of the form $b\{010\}$. Mr. T. V. Barker has kindly determined the forms present, and finds them to be only $b\{010\}$, $m\{110\}$, $n\{\bar{1}11\}$.

The deposition of these crystals was produced, I presume, by the gradual weakening of a solution of calcium sulphate in hydrochloric acid. There must have been plenty of lime and sulphuric acid about the works to furnish the gypsum. Calcium sulphate would be taken up by the hydrochloric acid, and subsequently, when the wasteful method of condensing the acid was discontinued, the acid solution would gradually weaken and crystals of gypsum be deposited.

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Crystallography of Sartorite from Binn.

(*With Plate V.*)

By CHARLES O. TRECHMANN, Ph.D., F.G.S.

[Read June 12, 1906.]

LITERATURE[1].

G. vom Rath, 'Mineralogische Mittheilungen (Fortsetzung III): II. Skleroklas.' Ann. Chem. Phys. (Poggendorff), 1864, vol. cxxii, pp. 380–387.

H. Baumhauer, 'Ueber den Skleroklas von Binn.' Sitzungsber. k. preuss. Akad. Wiss. Berlin, 1895, pp. 243–252.

R. H. Solly, 'Sulpharsenites of lead from the Binnenthal.' Min. Mag., 1900, vol. xii, pp. 282–297 (Sartorite on pp. 286 and 297). Translation in Zeits. Kryst. Min., 1891, vol. xxxv, pp. 321–344.

W. J. Lewis, 'A large crystal of sulpharsenite of lead from the Binnenthal.' Min. Mag., 1903, vol. xiii, p. xxxiv. (Analysis by H. Jackson.)

R. H. Solly, 'On sartorite . . . and other minerals from the Binnenthal.' Min. Mag., 1904, vol. xiv, p. xx. (Title only; abstract, giving angular elements, in 'Nature,' 1903, vol. lxix, p. 142.)

H. Baumhauer, 'Die Mineralien des Binnenthals.' Bull. Murithienne, Soc. valais. sci. nat., 1905, p. 35–49.

THE mineral sartorite (of Dana) or scleroclase (of v. Waltershausen) appears to have been found much more frequently in latter years in the well-known dolomite at the Lengenbach, in the Binnenthal, Switzerland, than was formerly the case, and it may now be considered to be one of the commonest of the group of sulpharsenites of lead which have made this locality famous. Large, detached, longitudinally striated, prismatic crystals, mostly devoid of terminal faces, have been especially frequent, the majority of which are doubtless sartorites.

Notwithstanding this abundance of material, there still exists some doubt respecting the system in which this mineral crystallizes. This is due to the peculiar development of a large proportion of the crystals, which are heavily striated and grooved in one direction, and without

[1] A more complete list of the earlier references is given by R. H. Solly, Min. Mag., 1900, vol. xii, p. 282.

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terminal faces, both ends of the crystal being attached to the dolomite matrix. When, in rarer cases, terminal faces are developed they appear brilliant, smooth, and unstriated, but all belonging to a single zone perpendicular to the striated one, thus affording no assistance towards a determination of the parameters. When pyramidal faces are present, which is exceedingly rare, they are frequently rounded or poorly developed on larger crystals, and on small ones either too minute, or situated in such a position with respect to the matrix that a removal of the crystal is practically impossible, owing to its extreme brittleness.

The latest detailed investigation of sartorite is due to Baumhauer (1895), who examined four crystals and determined on them a series of new forms. He enumerates a total of fifty-nine observed forms, among which are thirteen pyramids, though, as he himself states, a few of them are somewhat uncertain. Baumhauer describes, in agreement with the earlier investigation of vom Rath, this mineral as crystallizing in the orthorhombic system, though, as pointed out by himself, many of the forms only appear as single faces, whilst others exhibit very high and complicated indices.

The chemical composition is further elucidated by the analyses published by Solly (1900). These were made by Jackson on carefully selected crystals measured by the former, and lead to the assumption of the same formula as that adopted by vom Rath, viz. $PbS . As_2S_3$. A later analysis by Jackson (Lewis, 1903) also agrees closely with this formula, whilst Baumhauer, from an analysis made by König, is led to the formula $3(PbS . As_2S_3) + 2PbS . As_2S_3$.

The specific gravity, viz. 4·98 Solly, 5·05 Baumhauer, and 5·393 v. Waltershausen (cf. v. Rath), also shows some discrepancy. Solly (1903) further states that sartorite crystallizes, not in the orthorhombic, but in the monoclinic system, with the elements:

$$\beta = 88°31', \ (100):(101) = 54°45', \text{ and } (010):(111) = 69°52\tfrac{1}{2}'.$$

These data I have, however, been unable to harmonize with my own results.

On the occasion of a visit to the Binnenthal in August, 1904, I spent a day in company of Mr. Solly, with the men who work the dolomite quarry. A blasting shot was fired, and among other minerals a considerable number of specimens of sartorite were found, one or two of them exhibiting pyramidal faces. Among these and other purchased specimens were two which attracted attention on account of the brilliancy and perfection of form of small, presumably sartorite, crystals

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which they contained. These crystals form the principal subject of the following investigation.

The first specimen, about 4 cm. and 3 cm. in size, consisted of the usual white, granular dolomite, with some yellowish, coarser grained dolomite, some quartz, and a vein of massive sartorite, together with small crystals of realgar, pyrites, and a couple of minute binnites. In a small cavity was a crystal of sartorite of less than 2 mm. in size, on which a number of broad, smooth and highly polished faces were visible, developed in two zones perpendicular to each other, and on one corner, partially hidden by the matrix, a number of distinct pyramidal planes could be observed.

The second specimen, of similar size and component minerals with the exception of the realgar, also exhibited a small cavity in which, attached directly to the dolomite, was a group of three crystals. This group I was fortunately able to remove without fracture. It consisted of a doubly terminated sartorite about 2 mm. long and 1 mm. in each of the other dimensions, to which was attached a slightly smaller and shorter crystal of the same mineral, in what appeared to be a twinned position at an angle of about 45°, but in such a manner that the zone of the terminal faces of the second crystal was perpendicular to the same zone of the larger crystal. To the smaller crystal was attached a third crystal, at an indeterminate angle, which appeared to be rathite. The two sartorite crystals are distinguished by a beautifully developed series of terminal faces.

In the removal of the crystal of sartorite from the first specimen great care was exercised in the endeavour to obtain it unfractured; nevertheless, at the last moment, it broke, with an audible explosion, into several pieces. Very fortunately, however, the largest piece consisted of the greater part of the crystal, which had been visible on the matrix, and represented a practically complete individual. A second, smaller fragment consisted of an almost complete twinned crystal. The exact relative position of the larger to the smaller crystal was unfortunately not determinable, as the second crystal, while on the matrix, was hidden from view. It is, however, very probable that they were attached parallel to each other. These two crystals are referred to below as No. 1 and No. 2 respectively; the doubly terminated crystal from the second specimen as No. 3, and the one attached to it, in an apparently twinned position, is called No. 4. Nos. 5, 6, and 7 were received later.

The preliminary examination of Nos. 1 and 2, which are both under

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1 mm. in size, was made with the aid of a Zeiss-Greenough binocular microscope—a most efficient instrument for the purpose—and powers of 35 to 65 diameters, with the result that both crystals exhibited a conspicuous monoclinic habit, which I have endeavoured to reproduce as closely as possible after nature in figs. 1 and 3, plate V, in orthogonal projection on the plane of symmetry. Figs. 2 and 4 are meant to illustrate the same crystals in an ideal development, in order to show the zonal relationship of the faces to each other. The orthodomes therefore represent the macrodomes of the orthorhombic interpretation, and the prisms those of the brachydomes. The former, as the measurements indicated, were only found in single faces, whilst the latter usually appeared in symmetrical pairs in adjacent quadrants. A striking feature on crystal No. 1 was the extraordinarily rich development of the pyramidal faces, in which the negative hemipyramids in the two opposite octants largely exceed the positive ones in number, a relationship which is reversed in crystal No. 2. It is also worthy of note that many of the combination-edges of the pyramid-faces to each other and to the prism-faces incline considerably from right to left, being all parallel with each other in the projection. The feature, however, which gives the strongest monoclinic character to these two crystals is the presence of a number of distinct twin-lamellae, quite similar to, though narrower than, those so well known on jordanite, which traverse the pyramid- and clinodome-faces from top to bottom of the crystals, parallel to the orthopinacoid, but which are invisible on the prism-faces. The latter feature would seem to exclude the possibility of the anorthic system for these crystals. The majority of these twin-lamellae have been indicated on figs. 1 and 3 by dotted lines, and it will be noticed that in both crystals they appear in greatest number towards the central portion of the crystal, and that the outlying faces, i. e. those nearest to the orthopinacoids, are in some cases quite devoid of them. In harmony with this feature is the complete and undisturbed development of the large, smooth, and brilliant orthodome faces in the vicinity of a (100), and a considerable striation and grooving of the same faces nearer to c (001). This is not so apparent on the other side of the crystal around a' (100), where the crystal was closely invested by the matrix; here there is a considerable striation of the orthodomes and a repetition with a'. The face a (100) is narrow, but well developed, giving a very satisfactory reflection on the goniometer. a' (100) is larger, but terraced by repetition. The large orthodome- and the principal prism-faces are perfectly even and highly polished and give perfect

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reflections. The pyramid- and clinodome-faces, under a certain reflective angle of the light, appear slightly etched and velvety in appearance, but give, notwithstanding their minute dimensions, exceedingly good undisturbed reflections, which are very slightly affected by the faint secondary reflections of the twin-lamellae. The combination-edges of the various pyramids with one another and with the prisms and orthodomes are usually rounded and with a fused-like appearance, whilst those of the larger orthodomes and prisms are sharp and linear. The basal pinacoid c (001) was narrow, striated, and repeated, and unsuited for exact measurement, and the clinopinacoid b (010) was very narrow and rounded. Attached to the lower end of crystal No. 1 (see fig. 1) there remained a fragment of another crystal, marked II, which, according to the two well-developed orthodome-faces $2d$ (201) and $\frac{2}{3}d$ (803), represents a second individual in twinned position to the main crystal, and which would therefore form with the main crystal a contact or juxtaposition-twin on the same law as the twin-lamellae, viz. twin-plane a (100), but with the composition-plane perpendicular to the same. The two small visible pyramid-faces indicated on the figure were not elucidated.

Crystal No. 1 was measured through in almost all directions where zones could be followed, with the result that the monoclinic habit was distinctly confirmed, in harmony with the general appearance as already described. The measurements of the pyramid-faces, on account of their minute size and the rather weak, though distinct, reflections, were not used for fundamental angles, for which the very best reflections of the orthodomes and prisms were utilized. After some preliminary calculations, the following angles were selected for the determination of the parameters:

$$a : -d = (100) : (101) = \infty\bar{P}\infty : -\bar{P}\infty = 40°\,24\tfrac{1}{2}'$$
$$a' : \quad d = (\bar{1}00) : (\bar{1}01) = \infty\bar{P}\infty : \bar{P}\infty = 53°\,25'$$
$$a : \quad f = (100) : (110) = \infty\bar{P}\infty : \infty P = 51°\,16'$$

From which were calculated:

$$a : b : c = 1{\cdot}27552 : 1 : 1{\cdot}19487;$$
$$\beta = 77°\,48'.$$

The prisms therefore correspond to brachydomes of vom Rath and the orthodomes to his macrodomes, and I have retained the same letters for the generalized symbols of these forms, viz. f for the prisms and d for

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the orthodomes, to facilitate a comparison with the previous descriptions and figures of this mineral.

The axes $a:b:c$ selected by me furthermore correspond to the axes $c:b:a$ of vom Rath, with the distinction that my axes a and c are about twice as long as vom Rath's axes, which are $a:b:c=0{\cdot}539:1:0{\cdot}619$, whereby a system of axes of almost equal length has been obtained.

From this set of parameters I have calculated the indices of all the forms which were observed with reasonable certainty on crystals Nos. 1 and 2, and which are enumerated in Table I, together with the observed and calculated angles, the quality of the measurement, such as v. g. (very good), ca. (circa), &c., the number of observations of each face, and the nature of the face.

On the two crystals were observed 87 forms, consisting of the 3 pinacoids, 17 prisms, 6 clinodomes, 19 positive and 7 negative hemi-orthodomes, 35 pyramids, divided into 16 positive and 19 negative hemipyramids. Of the orthodomes only the following four pairs have corresponding indices in the positive and negative octants: $\pm 4d$, $\pm \frac{4}{3}d$, $\pm d$, and $\pm \frac{2}{3}d$. The eight pairs of pyramids with corresponding indices in the positive and negative octants are the following:

$e = \bar{1}11$ $r = 111$	$\pm$P	$v = \bar{2}41$ $q = 241$	$\pm 4\breve{P}2$
$\gamma = \bar{4}41$ $o = 441$	± 4P	$\tau = 322$ $n = 322$	$\pm \frac{3}{2}\bar{P}\frac{3}{2}$
$h = \bar{1}22$ $p = 122$	$\pm \breve{P}2$	$x = \bar{2}11$ $\nu = 211$	$\pm 2\bar{P}2$
$g = \bar{2}43$ $\mu = 243$	$\pm \frac{4}{3}\breve{P}2$	$\pi = 722$ $\nabla = 722$	$\pm \frac{7}{2}\bar{P}\frac{7}{2}$

At the end of Table I are added four further prisms, which were not observed on crystals Nos. 1 and 2. On none of the seven measured crystals was there found any indication of a plane at 90° to a (100), which would correspond with vom Rath's macropinacoid.

Crystal No. 2 requires a somewhat more detailed description. It was very small, barely $\frac{2}{3}$ mm. in the direction of the b axis, $\frac{1}{3}$ mm. in the a, and $\frac{1}{2}$ mm. in the c axis, and in habit very different from No. 1. The orthodome-zone was badly developed, much striated, and repeated, with very few distinct reflections. The orthopinacoid a (100) was very minute and curved, and the basal pinacoids c (001) were narrow, striated, and repeated, with poor reflections. The pyramid-faces were, however, smooth and polished, with rounded combination-edges, and

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TABLE I.

List of the Forms observed on Crystals No. 1 and No. 2; with the observed and calculated Angles.

No.	Letter or Symbol.	Indices. Miller.	Indices. Naumann.	Crystal. No. 1.	Crystal. No. 2.	Angles to $a = 100$. Calculated.	Angles to $a = 100$. Measured.	Angles to $a = 100$. Value.	Angles to other faces. Face.	Angles to other faces. Calculated.	Angles to other faces. Measured.	Angles to other faces. Value.	Number of Measured Angles.	Remarks.
Pinacoids :—						° ′	° ′			° ′	° ′			
1	a	100	$\infty\bar{P}\infty$	+	+	0 0								good face.
2	b	010	$\infty\breve{P}\infty$	+		90 0	90 4	ca.					1	very narrow, curved.
3	c	001	0 P	+	+	77 48	77 44 77 87	fair ca.					4	very narrow, uneven.
Prisms :—														
4	$20\bar{f}$	20.1.0	$\infty\bar{P}20$		+	3 34	3 34	ca.					1	very narrow.
5	$5\bar{f}$	510	$\infty\bar{P}5$	+	+	14 0	13 53 14 2	ca. ca.					2	narrow.
6	$\frac{9}{2}\bar{f}$	920	$\infty\bar{P}\frac{9}{2}$	+		15 29	15 29	fair					1	good.
7	$4\bar{f}$	410	$\infty\bar{P}4$	+		17 19	17 8	g.					1	good.
8	$\frac{7}{2}\bar{f}$	720	$\bar{P}\frac{7}{2}$	+		19 36	19 31 19 33	g. g.					2	narrow, distinct.
9	$3\bar{f}$	310	$\infty\bar{P}3$		+	22 34	21 35	g.					1	narrow, distinct.
10	$\frac{11}{4}\bar{f}$	11.4.0	$\infty\bar{P}\frac{11}{4}$		+	24 23	24 38	g.					1	narrow, distinct.
11	$\frac{5}{2}\bar{f}$	520	$\infty\bar{P}\frac{5}{2}$	+		26 30	26 30	v.g.					2	large, good.
12	$\frac{9}{4}\bar{f}$	940	$\infty\bar{P}\frac{9}{4}$	+		28 59	29 0	ca.					1	narrow.
13	$2\bar{f}$	210	$\infty\bar{P}2$	+	+	31 56	31 54	v.g.					2	large and smooth.
14	$\frac{11}{7}\bar{f}$	11.7.0	$\infty\bar{P}\frac{11}{7}$		+	38 26	38 18	fair					1	good.

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TABLE I (*continued*).

15	$\frac{4}{3}\bar{f}$	320	$\infty\bar{P}\frac{4}{3}$	+	+	39 44	89 44 89 48	v.g. v.g.	001	80 39	80 32	g.	8	large and smooth.
16	$\frac{4}{3}\bar{f}$	430	$\infty\bar{P}\frac{4}{3}$		+	43 5	42 55	g.					1	narrow, distinct.
17	f	110	∞P	+	+	Fund.	51 16	v.g.	001	82 24	82 31	g.	8	large and smooth.
18	$2\grave{f}$	120	$\infty\grave{P}2$	+	+	68 9	68 2 68 4	ca. ca.	001	85 29	85 33	g.	8	very narrow.
19	$3\grave{f}$	130	$\infty\grave{P}3$		+	75 2	75 48	ca.					1	very narrow, doubtful.
20	$\frac{1}{3}\frac{3}{3}\grave{f}$	2.13.0	$\infty\grave{P}\frac{1}{3}\frac{3}{3}$	+		82 58	82 56	ca.					1	very narrow.
Clinodomes :—														
21	a	023	$\frac{2}{3}\grave{P}\infty$	+		80 24			001	37 54	37 57	ca.	1	minute.
22	κ	045	$\frac{4}{3}\grave{P}\infty$	+		81 7			001	43 3	43 3	v.g.	1	distinct.
23	i	011	$\grave{P}\infty$	+		82 6	82 3	g.	001	49 26	49 23	g.	1	distinct.
24	y	065	$\frac{6}{5}\grave{P}\infty$	+		82 57			001	54 29	55 0	g.	1	minute, uneven.
25	l	085	$\frac{8}{5}\grave{P}\infty$	+		84 17			001	61 51	61 45	ca.	1	minute.
26	w	041	$4\grave{P}\infty$	+		87 28	87 37	ca.	001	77 55	78 7	ca.	1	long and narrow.
Orthodomes, positive :—														
27	$9d$	$\bar{5}01$	$9\bar{P}\infty$	+		6 46	6 53	ca.					1	very narrow.
28	$8d$	$\bar{5}01$	$8\bar{P}\infty$	+		7 39	7 38	fair					1	distinct, striated.
29	$\frac{9}{2}d$	$\bar{5}02$	$\frac{9}{2}\bar{P}\infty$	+		18 43	18 50	v.g.					1	good and smooth.
30	$\frac{2}{3}\frac{1}{0}d$	$\bar{2}1.0.5$	$\frac{2}{3}\frac{1}{0}\bar{P}\infty$	+		14 43	14 48	fair					1	distinct.
31	$4d$	$\bar{4}01$	$4\bar{P}\infty$	+	+	15 27	15 29	v.g.					8	large and smooth.
32	$\frac{8}{3}d$	$\bar{8}03$	$\frac{8}{3}\bar{P}\infty$	+		23 9	23 10	g.					1	fair, disturbed.
33	$\frac{4}{3}d$	$\bar{5}02$	$\frac{4}{3}\bar{P}\infty$		+	24 39	25 2	fair					1	narrow, distinct.
34	$2d$	$\bar{2}01$	$2\bar{P}\infty$	+		30 27	30 35 30 27 30 29	fair v.g. g.					8	large and smooth.

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TABLE I (*continued*).

No.	Letter or Symbol.	Indices.		Crystal.		Angles							Number of Measured Angles.	Remarks.
						to $a = 100$.			to other faces.					
		Miller.	Naumann.	No. 1.	No. 2.	Calculated.	Measured.	Value.	Face.	Calculated.	Measured.	Value.		
Orthodomes, positive (*continued*) :—						° ′	° ′			° ′	° ′			
35	$\frac{1}{3}d$	905	$\frac{1}{3}\bar{P}\infty$	+	+	33 32	34 14 fair 34 0 do. 34 1 do.						3	very narrow.
36	$\frac{1}{3}d$	805	$\frac{1}{3}\bar{P}\infty$	+		37 12	37 9	fair					1	narrow, distinct.
37	$\frac{1}{3}d$	302	$\frac{1}{3}\bar{P}\infty$		+	39 18	40 85	fair					1	small, distinct.
38	$\frac{1}{3}d$	403	$\frac{1}{3}\bar{P}\infty$	+		43 17	43 27	ca.					1	very narrow.
39	$\frac{1}{4}d$	504	$\frac{1}{4}\bar{P}\infty$	+	+	45 32	45 43 fair 45 26 do.						3	very narrow.
40	d	101	$\bar{P}\infty$	+	+	Fund. $\not{x}$	53 25	v.g.					4	distinct and smooth.
41	$\frac{1}{19}d$	19.0.20	$\frac{1}{19}\bar{P}\infty$		+	55 14	55 22	fair					1	distinct, striated.
42	$\frac{7}{10}d$	7.0.10	$\frac{7}{10}\bar{P}\infty$	+		65 33	65 2	ca.					1	very narrow.
43	$\frac{1}{3}d$	203	$\frac{1}{3}\bar{P}\infty$		+	67 5	66 45	fair					1	very narrow.
44	$\frac{1}{7}d$	407	$\frac{1}{7}\bar{P}\infty$	+	+	71 40	71 55 fair 71 44 ca.						2	narrow, striated.
45	$\frac{1}{7}d$	207	$\frac{1}{7}\bar{P}\infty$		+	86 42	86 47	fair					1	narrow, rough.
Orthodomes, negative :—														
46	$-4d$	401	$-4\bar{P}\infty$	+		18 52	18 34	fair					1	narrow, distinct.
47	$-\frac{1}{3}d$	403	$-\frac{1}{3}\bar{P}\infty$	+	+	33 48	33 58 v.g. 33 51 fair						2	large, striated.
48	$-^{7}d$	706	$-\frac{1}{7}\bar{P}\infty$			36 51	36 42	fair					1	narrow, distinct.

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TABLE I (*continued*).

49	$-d$	101	$-\bar{P}\infty$	+	+	Fund ~~$\frac{1}{2}$~~	40 24½	v.g.					3	large broad face, good.
50	$-\frac{1}{11}d$	11·0·12	$-\frac{1}{11}\bar{P}\infty$	+		42 25	42 25	fair					1	narrow, striated.
51	$-\frac{1}{8}d$	804	$-\frac{1}{8}\bar{P}\infty$	+		46 55	46 1	ca.					1	very narrow, indistinct.
52	$-\frac{1}{7}d$	207	$-\frac{1}{7}\bar{P}\infty$		+	63 45	64 20	fair					1	distinct.
Pyramids :—														
53	e	111	P	+	+	64 82	64 35 64 22	ca. fair	110	35 59	35 55 35 59	fair	2	small, distinct.
54	γ	441	4 P		+	52 12			110	9 36	9 42	g.	1	small, distinct.
55	ρ	113	$-\frac{1}{3}$ P		+	63 33			110	57 31	57 4	ca.	1	very small.
56	Δ	445	$-\frac{4}{5}$ P	+		54 36			110	36 42	36 48	g.	1	very small, distinct.
57	r	111	$-$P	+	+	52 59	52 59 53 2 53 8	g. ca. v.g.	110	31 19	31 20 31 8 31 26 24 47	fair g. g. g.	3	small, good.
58	m	443	$-\frac{4}{3}$ P		+	51 32			110	24 58	24 55 24 58	fair do.	3	small, distinct.
59	z	221	-2 P		+	50 32			110	17 36	17 9	ca.	1	very small, curved.
60	o	441	-4 P	+	+	50 20	50 29	g.	110	9 12	9 9 9 9	fair g.	3	small, distinct.
61	H	344 or 799	$\frac{2}{3}\dot{P}\frac{2}{3}$ or $\frac{2}{7}\dot{P}\frac{2}{7}$		+	72 7 71 14	71 7	ca.					1	small, narrow, distinct.
62	δ	166	$\dot{P}6$	+		92 5	92 3	ca.					1	very small.
63	u	123	$\frac{2}{3}\dot{P}2$	+	+	85 23			120	52 40	52 30 52 48	ca. ca.	3	very small.
64	ϵ	245	$\frac{1}{3}\dot{P}2$	+	+	83 6			120	47 3	47 1 47 3	fair v.g.	3	small, distinct.
65	h	122	$\dot{P}2$	+	+	80 25	80 6 80 24	g. g.	120	40 12	40 8 40 12	g. g.	3	large and distinct.
66	g	243	$\frac{1}{3}\dot{P}2$		+	77 20			120	31 56	31 54	g.	1	small, distinct.

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TABLE I (*continued*).

No.	Letter or Symbol.	Indices.		Crystal.		Angles to $a = 100$			Angles to other faces.				Number of Measured Angles.	Remarks.
		Miller.	Naumann.	No. 1.	No. 2.	Calculated.	Measured.	Value.	Face.	Calculated	Measured.	Value.		
						° ′	° ′			° ′	° ′			
67	β	$\bar{1}21$	$2\dot{P}2$		+	74 0			120	22 14	22 14	g.	1	small, distinct.
68	R	$\bar{4}83$	$\frac{8}{3}\dot{P}2$		+	72 22			120	16 55	17 8	ca.	1	very small.
69	v	$\bar{2}41$	$4\dot{P}2$	+		70 48	70 41		120	11 22			1	narrow, distinct.
70	p	122	$-\dot{P}2$	+		65 57	65 55	g.	120	36 43	36 44	ca.	2	large, distinct.
71	A	5.10.8	$-\frac{5}{4}\dot{P}2$	+		65 36			120	31 7	30 31	ca.	1	very narrow.
72	μ	243	$-\frac{3}{2}\dot{P}2$		+	65 33			120	29 34	29 33	fair	1	very small, distinct.
73	q	241	$-4\dot{P}2$	+		66 24	66 58	g.	120	11 2	10 56	g.	1	small, distinct.
74	x	$\bar{2}11$	$2\bar{P}2$		+	42 30	42 23	fair					1	very small, distinct.
75	ν	211	$-2\bar{P}2$	+		36 9	36 6	g.					1	small, distinct.
76	D	$\bar{6}41$	$6\bar{P}\frac{3}{2}$		+	41 25			320	7 52	7 58	fair	1	small, distinct.
77	σ	645	$-\frac{6}{5}\bar{P}\frac{3}{2}$	+		45 21			320	31 17	30 56	ca.	1	very small, doubtful.
78	s	643	$-2\bar{P}\frac{3}{2}$	+	+	41 24			320	20 47	20 35 21 8	g. ca.	2	large, distinct.
79	t	321	$-3\bar{P}\frac{3}{2}$	+		39 58			320	14 30	14 18	fair	1	small, distinct.
80	Y	21.14.8	$-7\bar{P}\frac{7}{2}$		+	39 17			320	6 29	6 35	ca.	1	long and very narrow, curved.

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TABLE I (*continued*).

81	τ	322	$\frac{3}{4}\bar{P}\frac{3}{4}$		+	51 54	51 48	v.g.	320	30 39	30 38	v.g.	1	large and smooth.
82	π	722	$\frac{7}{2}\bar{P}\frac{7}{2}$	+		26 24	26 32	ca.					1	very narrow.
83	η	511	$6\bar{P}6$	+		15 43	15 5	ca.					1	very narrow, doubtful.
84	n	322	$-\frac{3}{4}\bar{P}\frac{3}{4}$	+	+	43 18	43 22 43 23 43 13	v.g. fair g.	320	26 23	26 25 26 22	g. ca.	8	large, very good.
85	V	722	$-\frac{7}{2}\bar{P}\frac{7}{2}$	+		23 35	24 25	ca.					1	very small, doubtful.
86	N	411	$-4\bar{P}4$	+		21 3	21 47	ca.					1	very small, doubtful.
87	C	12.1.1	$-12\bar{P}12$	+		7 34	7 28	ca.					1	very small, doubtful.

Prisms, observed on other Crystals:

				No. 5.	No. 6.	No. 7.								
	$\frac{11}{3}\bar{f}$	11.2.0	$\infty\bar{P}\frac{11}{3}$	+			12 46	12 56	ca.				1	very narrow, striated.
	$\frac{11}{9}\bar{f}$	11.5.0	$\infty\bar{P}\frac{11}{9}$			+	29 32	29 28	fair				1	narrow, distinct.
	$\frac{4}{3}\bar{f}$	540	$\infty\bar{P}\frac{4}{3}$		+	+	44 55	44 48	v.g.				2	broad, good.
	$4\breve{f}$	140	$\infty\breve{P}4$	+		+	78 40	78 36	g.				2	broad, good.

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traversed, exactly as in No. 1, with many twin-lamellae parallel to a (100), of which the most prominent are indicated in fig. 3 by dotted lines. The prism-faces were also smooth and brilliant, but very small and repeated, thus obscuring the zones, which were so clear and prominent in No. 1. The monoclinic habit was, however, quite evident, and the twinned nature clearly indicated by the reentrant angle of the basal pinacoids. On account of the inferior development of leading planes, it was found impossible to unravel this crystal, until the complete calculations on No. 1 had been made, and all its faces determined; it was then found that the three zones [*ueh*], [*for*], and [*nrh*] agreed in their angles with those of No. 1. Thereupon the best reflections, viz. those from the faces *h* and *f*, were utilized as a foundation for the determination of the observed faces, with the result shown on Table I, in which the measured angles agree fairly well with the calculated ones.

As is indicated in fig. 3, this crystal consists of three individuals, attached to each other on the face a (100) as twin-plane, in such a manner that the central individual appears inserted as a broad twin-lamella between the two exterior ones. The twinning edge is clearly developed in the upper half of the crystal between I on the right hand and II, but in the lower part, and between I on the left and II, is obscured, partly by fracture and partly by a very small protruding crystal in the position I. The faces h, ϵ, u and h, $\underline{\epsilon}$, $\underline{u}$ give respectively the following (non-reentrant) angles:

$h : \underline{h}$	calculated	19°10′,	observed	19°12′
$\epsilon : \underline{\epsilon}$	,,	13°47′	,,	14°14′
$u : \underline{u}$	,,	9°15′	,,	10° 1′
$c : \underline{c}$	,,	24°24′	,,	24°11′

Fig. 4 is meant to represent this crystal in an ideal development, with the principal forms observed on it.

It will be noticed that the clinodomes are totally absent, and that there is a richer development of the positive hemipyramids as compared with crystal No. 1: we find 12 of them, as against 8 on No. 1, and 9 negative hemipyramids corresponding with 14 on No. 1. It is very strange that only eight pyramids are common to both crystals, viz. *e*, *r*, *o*, *u*, ϵ, *h*, *s*, and *n*, which, however, represent those with simpler indices, and belonging to the principal zones. This feature seems to be of some significance: for if such widely different sets of related forms are found on two crystals, which were originally attached to each other

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and probably in twinned position, then it might be expected that still wider differences would be observed on crystals from other specimens: and this may in part explain the want of agreement between the observations made on different crystals of sartorite by other investigators.

On my crystals Nos. 1 and 2 other pyramidal faces could be detected, but they defied measurement on account of their minute size, or their hidden position. In fig. 5 almost all the forms observed on crystals Nos. 1 and 2 have been represented in a stereographic projection on the plane of symmetry.

The most important question which arises out of the above observations, is whether these crystals are actually sartorite or whether they belong to some other mineral. The crystals are so small that any chemical test is out of the question; so also is a determination of the specific gravity. A distinct cleavage was nowhere observable on any of the crystals examined by me. The only means of identification remaining are the geometrical form and the streak. The latter was examined on minute fragments from crystals Nos. 1, 2, 5, and 6, and found to be practically the same with all of them, viz. reddish-chocolate, in harmony with the statement of vom Rath. On the other hand, a very similar streak is given by the related minerals dufrenoysite, rathite, and baumhauerite, so that this character is not much to be relied upon.

With respect to the geometrical form there is already a considerable diversity between the forms given by vom Rath and by Baumhauer, especially, as has been pointed out by the latter, among the macrodomes (see l. c., p. 249). On the other hand, four of the five brachydomes observed by vom Rath are repeatedly observed again by Baumhauer. On the seven crystals, which I have examined, the measurements of the orthodomes show so little similarity that I have found it impossible to harmonize them either with each other, or with those observed by vom Rath and Baumhauer. Even between the crystals Nos. 1 and 2 there is so little similarity, notwithstanding the fact that these two crystals undoubtedly belong to the same larger one, and are of the same substance, that only five positive and two negative hemiorthodomes, out of a total of twenty-six, appear on both of them.

On the crystals Nos. 3 and 4, notwithstanding the exceptionally perfect development of the prism-zone and the orthopinacoids, the orthodomes could not be determined at all, for the whole zone of these, on both crystals, gave a continuous series of grouped reflections, due to the fine striation, so that not a single individualized reflection could be noted. The crystals Nos. 5, 6, and 7 gave some very satisfactory

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reflections, but in no case could they with certainty be brought into harmony with the orthodomes observed on Nos. 1 and 2; even on one and the same crystal, what appeared to be corresponding faces gave very variable angles. The impression conveyed is that the faces of this zone are profoundly influenced by repeated twinning or some other as yet unexplainable cause.

Only in the prism, or brachydome, zone of all hitherto described crystals is there found an unexpected and striking similarity, which I have attempted to show on the comparative Table II. It contains the whole of the brachydomes given by vom Rath and Baumhauer and all the prisms observed on my crystals Nos. 1 to 7, together with the calculated and the principal measured angles. It will be at once noticed that the forms most frequently observed by me correspond in the angles with those most often observed by the above-named authors, and that there exists a fairly close agreement between the measured and calculated angles.

In Table III I have furthermore tabulated, for the four most frequent prisms, all my best measurements, in order to indicate the fluctuations on one and the same and on different crystals. A comparison of these results with each other and with previous observations would seem to justify the assumption that all my seven crystals actually belong to the mineral sartorite.

On the crystals Nos. 3 and 4, there was no indication of the presence of any pyramidal faces. No. 7, a well-formed crystal of the ordinary type, showed a few rounded indeterminable pyramids. Crystals No. 5 and 6 were derived from a very small specimen of dolomite, and represent the upper and lower terminations of one and the same somewhat larger crystal, the central portion of which was overlaid by a similar one, almost at right angles to it, such as has been referred to by Baumhauer (l. c., p. 251) as being possibly a twin-formation. This rectangular intergrowth of sartorite is a not uncommon occurrence. Both of these crystals have a rich development of pyramidal faces, of which forty-five were counted on No. 5 and about thirteen on No. 6. Twin-lamellae were distinctly observable on both crystals, but especially on No. 6, where some of the faces were quite devoid of them, and others were closely intersected. The zonal relations of these pyramidal faces were, however, so indistinct, and most of them were so small, that it has not been possible so far to identify them. Some measurements made on crystal No. 6 could not be harmonized with Nos. 1 and 2, nor with the pyramids observed by Baumhauer.

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TABLE II.—COMPARISON OF THE OBSERVED PRISMS WITH THE BRACHYDOMES OF VOM RATH AND BAUMHAUER.

Symbol.		v. Rath & Baumh.		C.O.T,		Observed by		Number of measured edges.	C O.T. observed on Crystal No.							Number of measured edges.
		to $c = 001$.		to $a = 100$.												
C.O.T.	v.R. & B.	Calculated.	Observed	Calculated.	Observed.	v. R.	B.		1	2	3	4	5	6	7	
$20\bar{f}$				3° 34′	3° 34′					+						1
$\frac{1}{19}\bar{f}$	$\frac{4}{17}f$	12° 41′	12° 38′	12 46	12 56		+[2]	2					+			1
$5\bar{f}$	$\frac{1}{4}f$	13 54½	14 2	14 0	14 2		+	2	+	+					+	3
$\frac{9}{2}\bar{f}$	$\frac{2}{9}f$	15 34	15 29	15 29	15 29		+	1	+						+	2
	$\frac{7}{15}f$	16 7	16 5				+	1 uncertain								
$4\bar{f}$	$\frac{1}{3}f$	17 12	17 16	17 19	17 8		+[2]	2	+						+	2
$\frac{7}{2}\bar{f}$	$\frac{4}{7}f$	19 28	19 30	19 36	19 32		+	1	+[2]				+	+[2]		5
$3\bar{f}$	$\frac{2}{5}f$	22 25	22 24	22 34	21 35		+[2]	2		+						1 uncertain
$\frac{11}{4}\bar{f}$				24 23	24 38					+						1
$\frac{8}{3}\bar{f}$	$\frac{4}{9}f$	26 20	26 10-20	26 30	26 30		+	2	+[2]		+[4]	+	+[2]	+[2]	+	12
	$\frac{3}{7}f$	27 17	27 6				+	1 uncertain								
$\frac{2}{1}\bar{f}$				28 59	29 0				+							1
$\frac{11}{5}\bar{f}$				29 32	29 23										+	1
	$\frac{14}{15}f$	30 0	30 1				+	1								
$2\bar{f}$	f	31 45	31 54	31 56	31 54	+	+	3	+	+				+		3
$\frac{11}{7}\bar{f}$				38 26	38 18					+						1
$\frac{5}{2}\bar{f}$	$\frac{4}{5}f$	39 31	39 41	39 44	39 44-48	+	+	5	+[2]	+	+[4]	+	+	+[7]	+	12
	$\frac{11}{10}f$	40 14	40 15				+	1								
$3\bar{f}$	$\frac{8}{7}f$	42 52	43 28	43 5	42 55	+		1		+			+	+		3
	$\frac{17}{16}f$	44 7	44 18				+	1 uncertain								
$\frac{4}{1}\bar{f}$				44 55	44 48									+	+	2
	$\frac{17}{16}f$	46 27	46 32				+	1 uncertain								
	$\frac{23}{21}f$	47 1	47 6				+	1								
	$\frac{13}{12}f$	50 7	50 3-6				+	2								
f	$2f$	51 4	51 10-14	51 16	51 16	+	+[5]	7	+[2]	+	+[4]	+[2]	+[2]	+	+[2]	14
$2f$	$4f$	68 0	68 4	68 9	68 2-10	+	+[6]	8	+[2]	+	+[4]	+[2]	+[2]	+	+[2]	14
$3f$				75 2	75 48					+						1 uncertain
$4f$				78 40	78 36								+		+	2
$\frac{1}{2}f$				82 58	82 56				+							1
b	010	90 0	90 0	90 0	90 0	+	+	2	+		+[2]	+	+		+	6

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TABLE III.—Fluctuations of the Angles of the Principal Prisms.

Symbol.	Indices.		Angles to $a = 100$.							
				Measured on Crystal No.						
	Miller.	Naumann.	Calculated.	1	2	3	4	5	6	7
$\frac{4}{3}\breve{f}$	520	$\infty \bar{P} \frac{4}{3}$	° ′ 26 30	° ′ 26 30½ 18	° ′	° ′ 26 25 26 16½ 37½	° ′ 26 25½	° ′	° ′	° ′ 26 24
$\frac{3}{2}\breve{f}$	320	$\infty \bar{P} \frac{3}{2}$	39 44	39 48	39 44	39 38 38½ 17½ 46	39 34½		39 34	39 36
f	110	∞ P	51 16	51 16½ 15½	51 8	51 9½ 13½ 4 21½	51 6	51 7	51 6½	51 8 6½
$2\breve{f}$	120	$\infty \breve{P} 2$	68 9			68 10½	68 11 5½	68 8		68 2½ 2½

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It may be mentioned that in the determination of the orthodomes of Nos. 1 and 2 only distinct and individualized reflections were made use of; all such as were grouped or coloured were rejected, or only used to corroborate better reflections. All the measurements were made on a Fuess No. 2 horizontal-circle goniometer, with the eyepiece γ, a small angle of incidence, and a Websky slit illuminated by an incandescent gas-lamp and the condensing lens. Even the smallest pyramidal faces, owing to their brilliancy, gave distinct and individualized reflections, and may, therefore, with few exceptions, be considered as safely determined.

With less confidence would I wish it to be assumed that the crystals Nos. 1 and 2 are, beyond any doubt, to be considered as sartorites. It is not impossible that we have here to deal with a case similar to that of the humite group, in which several closely allied substances possess identical or almost identical angles in one zone, and different ones in the zone perpendicular to the first. It is also possible that such morphotropic substances may form lamellar intergrowths, and thus obscure the crystallographic properties of each other. An apparent lamellar structure is observable on fractured surfaces of sartorite, and is also visible on crystals Nos. 1 and 2.

Further observations are necessary in order to clear up the difficulties and discrepancies still attaching to even the most perfect crystals of this mineral, and it is hoped that this contribution may draw renewed attention towards it.

Explanation of Plate V.

Crystals of Sartorite from the Binnenthal, Switzerland.

Orthogonal projections on the plane of symmetry. (The dotted lines represent twin-lamellae parallel to a (100).)

Fig. 1.—Crystal No. 1; actual development.

Fig. 2.—The same; ideal development.

Fig. 3.—Crystal No. 2; actual development of twinned crystal.

Fig. 4.—The same; ideal development.

Fig. 5.—Stereographic projection on the plane of symmetry, showing most of the forms observed on crystals Nos. 1 and 2.

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Notes on skiodroms and isogyres.

By JOHN W. EVANS, LL.B., D.Sc., F.G.S.

Adviser in Mineralogy to the Scientific and Technical Department of the Imperial Institute.

[Read June 12, 1906.]

PROFESSOR BECKE'S paper[1] on skiodroms marks an important advance in our knowledge of the shadows, or isogyres, which are seen when sections of crystals are examined in convergent polarized light. The isogyres can also be advantageously studied in mineral grains, where the irregular shape disturbs the distribution of the interference colours, but has much less effect on the shadows due to the coincidence of directions of vibration in the crystal with those of one of the nicols.

Throughout Professor Becke's communication[2] the movements of these dark bars or brushes are described as they are seen in a microscope where the stage rotates and the nicols are fixed, such as is almost invariably used in Germany. The fact that the section is not fixed relatively to the field of the microscope is a serious disadvantage, for the movement of the stage is superposed on that of the shadows relatively to the fundamental optical directions of the crystal, so that it is somewhat difficult to realize the true nature of the latter movement.

If, however, a microscope with fixed stage and revolving nicols be employed, the optical directions remain unchanged in position and the whole investigation is simplified, so that the variations in form and position of the shadows, or isogyres, as the nicols rotate, and their connexion with the skiodroms can be easily followed. With rotating nicols there is no difficulty in sketching under a camera-lucida, not only different positions of the isogyres, but also the forms of the skiodroms in the section under examination.

I shall accordingly concisely describe and explain the shadow phenomena seen in a microscope with a fixed stage and revolving nicols and, as in the abstract (p. 278), shall for brevity's sake confine myself to

[1] 'Die Skiodromen. Ein Hilfsmittel bei der Ableitung der Interferenzbilder.' Min. Petr. Mitt. (Tschermak), 1905, vol. xxiv, pp. 1-34; abstracted on p. 276 of this volume.

[2] Except for a brief allusion on p. 12.

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sections which do not show an axis of optical symmetry or an optic axis, though the same principles may easily be extended to such cases.

In oblique sections of uniaxial crystals the longitudinal skiodroms (which are here meridian) converge towards the optic axis. They are at the same time slightly concave to the straight longitudinal skiodrom that passes through the centre. As the nicols are rotated, the isogyre moves across the field approximately in the same manner as if it were rotating with the angular velocity of the nicols about the optic axis, but the end further from the optic axis moves slightly faster than if that were the case—a result of the curvature of the lateral longitudinal skiodroms.

The terms homodrom and antidrom are now no longer applicable, as the end nearer the optic axis (the so-called homodrom end) moves round the circumference of the field in the opposite angular direction to that in which the nicols rotate, while the end further from the optic axis (the antidrom end) moves round with the nicols. I, therefore, propose to employ the epithet 'proximal' for the end of the isogyre and the margin of the field nearer the optic axis, and 'distal' for those directed away from it. The same terms may be employed by analogy in the case of biaxial crystals. The margin of the field and the end of the isogyre on the side towards which the longitudinal skiodroms converge will be proximal, and those on the opposite side will be distal. Here, too, the proximal end of the isogyre moves round the circumference of the field in an angular direction contrary to that in which the nicols revolve, and the distal end in the same direction as the nicols. (See figs. 3 and 6.)

In sections whose normal lies in the optic axial plane of a biaxial crystal the disposition of the skiodroms and movement of the isogyres present considerable resemblance to those in an oblique section of a uniaxial crystal. The lateral longitudinal skiodroms converge in the direction of the nearest optic axis, which therefore lies on the proximal side of the field. They are markedly concave towards the central skiodrom and accordingly make a less angle with it on the distal margin than on the proximal. The distal end of the isogyre therefore moves with much greater velocity than the proximal end, and when it reaches the periphery of the field it is strongly curved outwards. The pendulum motion is much more vigorous than when the stage, and not the nicols, rotates. (See figs. 1–3.)

In sections whose normal lies in a plane of optical symmetry, including a bisectrix and the optic normal, the longitudinal skiodroms converge towards the bisectrix, but they are convex towards the central

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skiodrom and are therefore more inclined to it on the distal than on the proximal side of the bisectrix. The proximal end of the isogyre therefore moves faster than the distal end, but this character is less marked than when the stage rotates instead of the nicols. (See figs. 4–6.)

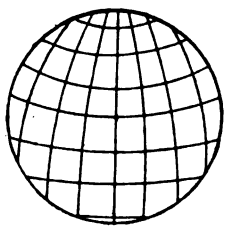

Fig. 1.

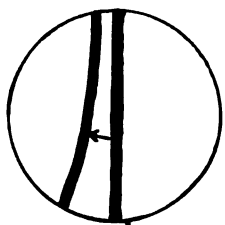

Fig. 2.

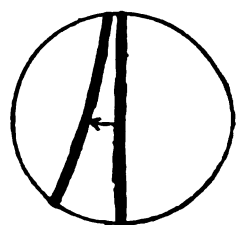

Fig. 3.

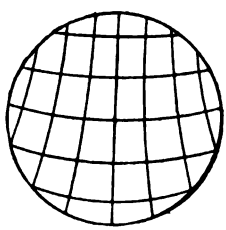

Fig. 4.

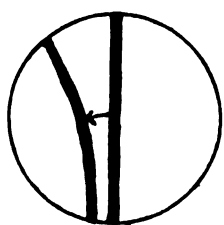

Fig. 5.

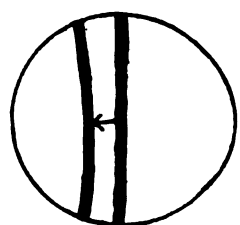

Fig. 6.

EXPLANATION OF FIGURES.

Fig. 1.—Skiodrom-net for a section whose normal lies in the optic axial plane.

Fig. 2.—Movement of the isogyre in such a section when the *stage* is rotated anticlockwise.

Fig. 3.—Movement of the isogyre in the same section when the *nicols* are rotated through the same angle clockwise.

Fig. 4.—Skiodrom-net for a section whose normal lies in a plane of optical symmetry passing through a bisectrix and the optic normal.

Fig. 5.—Movement of the isogyre in such a section when the *stage* is rotated anticlockwise.

Fig. 6.—Movement of the isogyre in such a section when the *nicols* are rotated clockwise.

Figs. 2, 3, 5, and 6 each show two positions of the isogyre: (i) the central position parallel to one of the nicols, and (ii) that after rotation of the stage or nicols through an angle equal to that between the lower end of the central isogyre and the short line across the point of the arrow below the circle.

Figs. 1 and 4 are copied from Professor Becke's paper. Compare figs. 1 and 2 on p. 277 of this volume.

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If the section-normal does not lie in a plane of optical symmetry, the movement of the isogyre will be essentially similar to one of the types already described, but the movements, like the skiodroms, will be asymmetrical.

There is another point of nomenclature in which I would suggest a change. The use of the expression a- or γ-ellipses is open to misconception, as a properly denotes the minimum and γ the maximum index of refraction in the crystal. I would prefer to speak of fast and slow ellipses, or skiodroms, and of a section where the longitudinal skiodroms are fast or slow as having a fast or slow instead of a positive or negative reaction.

Professor Becke's rule for determining the sign or character of the reaction of a section may be easily employed in a microscope with rotating nicols. The nicols are rotated till the isogyre passes through the centre of the field. The cross-wire that is parallel with the isogyre at the centre, or makes an angle of less than 45° with it, is taken as the geographical meridian and the direction of the proximal margin as the north; the rule will then be applied exactly in the same manner as stated in the abstract (p. 279).

In some cases, especially if the rate of change of the relative retardation from point to point in the image in convergent light be very great, it is difficult to apply the Becke rule. It is then better, after ascertaining the direction of the longitudinal skiodrom at the centre (which is that of the cross-wire parallel to the central isogyre, or making with it an angle less than 45°), to rotate the nicols through 45° and to determine by means of the quartz-wedge in parallel light whether the vibrations parallel to the longitudinal skiodrom are faster or slower than those at right angles to it.

The direction of the cross-wire which is parallel to the central isogyre, or makes an angle of less than 45° with it, may be conveniently referred to as the longitudinal extinction, and that at right angles to it as the transverse extinction. These extinctions may also be referred to as fast or slow, according as they are parallel to the fast or slow vibrations. If, then, the longitudinal extinction be fast or slow, the reaction of the section will have the same character.

There are some sections in which the isogyre is so ill-defined that it is difficult or impossible to determine the direction of the longitudinal skiodroms. This may be due to the fact that the section-normal is too far removed from the optic axial plane, or to strain or other optical abnormalities. In such cases it is useful to remember that the proximal

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margin of the field is that which shows the lowest relative retardation or 'colour'; for the birefringence diminishes as the optic axes are approached, and with an objective of any ordinary aperture the greater length traversed in the crystals by light in the periphery of the field is not sufficient to counteract the decrease in the birefringence. The portion of the field in which the relative retardation is least may be roughly ascertained by rotating the nicols through 45° from the position of extinction in parallel polarized light, and inserting a gypsum-plate over the image in convergent light. The region of the lowest relative retardation is that in which the colour approximates most nearly to that of the plate when inserted alone [1].

This method is not applicable where the relative retardation is very high; it is then necessary to use a quartz-wedge inserted in the focus of the eyepiece in convergent light under the same conditions as those just mentioned for the gypsum-plate. The coloured bands will then usually be curved or inclined. If the wedge be in the position of compensation, the bands will, where the relative retardation is less, be advanced nearer to the thin end of the wedge. If, on the other hand, the wedge be in the additive position, the bands will, where the birefringence is less, be retracted towards the thick end. By inserting the wedge in parallel light, first in one direction of extinction and then in the other, it is possible to determine the portion of the periphery where the relative retardation is lowest; this will be the direction of the proximal end of the central longitudinal skiodrom. The same observation will also have determined whether this is the direction of the faster or slower vibration, and what is the sign or character of the reaction of the section.

Mr. H. Hilton's paper [2] on the application of the gnomonic projection to isogyres in the neighbourhood of the centre of the field, recalls an unpublished suggestion of my own; namely, that, with a view to using the same projection, an objective with a plane focal surface for light from infinite distance should be employed. I find on inquiry that objectives practically satisfying this condition are already manufactured in this country.

[1] The use of the gypsum-plate in this way to determine the direction of the acute bisectrix in a section at right angles to the optic normal was first introduced by Professor Becke, Min. Petr. Mitt. (Tschermak), 1897, vol. xvi, p. 181.

[2] Zeits. Kryst. Min., 1906, vol. xlii, p. 277; abstract in this vol., p. 281.

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Communications from the Oxford Mineralogical Laboratory. No. VIII.

On the regular growth of soluble salts on each other.

By Thomas Vipond Barker, B.A., B.Sc. (Oxon.)
Senior Demy of Magdalen College, Oxford.

[Read November 13, 1906.]

PREVIOUS work on the regular growth of crystals of salts on those of Minerals belonging to the same isostructural series led the author [1] to the discovery that parallel deposition is conditioned by closeness, not of angle nor of axial ratios, but of molecular volume. Now although the substances previously examined resemble each other crystallographically, yet they exhibit such great differences in chemical properties, that reasonable doubt might be entertained whether conclusions drawn from them can be directly applied to isomorphous substances; and it therefore became advisable to extend the observations to a group of the latter.

The group selected should, from the nature of the problem, not only be numerous but should also exhibit great differences of molecular volume amongst its members. Now the largest isomorphous group known is that of the double sulphates and selenates, which has been so thoroughly investigated by Tutton; this group, however, like that of the alums, does not fulfil the second condition, for the range of molecular volume is comparatively small: this results from the high molecular weight associated with the relatively small amount of chemical substitution. A suitable group is met with in the chlorides, bromides, iodides, and cyanides of sodium, potassium, rubidium, caesium, and ammonium, which crystallize in the cubic system; further, the majority of the salts possess a perfect cubic cleavage, so that there is no difficulty in obtaining clean surfaces.

Of the above salts, rubidium and caesium cyanides have not been

[1] T. V. Barker, 'Contributions to the theory of isomorphism based on experiments on the regular growths of crystals of one substance on those of another.' Journ. Chem. Soc. Trans., 1906, vol. lxxxix, pp. 1130–1158.

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previously described; but, although the published crystallographic data concerning the remaining salts leave little to be desired individually, yet great uncertainties exist with regard to their relationships as a whole. Thus, ammonium chloride and bromide cannot be obtained in cubes without the addition of other substances—especially urea—to their solutions, and the crystals so obtained exhibit only a very poor cleavage: the miscibility, again, of some of the pairs investigated is vanishingly small: finally, etching experiments point to a difference of symmetry. For the above reasons, strict isomorphism has been denied, and evidence for at least dimorphism has been adduced by Lehmann, Groth, and others.

It might therefore seem that a careful investigation of the group was imperative before carrying out experiments on parallel growths. But the latter have been taken in hand first, in order to see whether they can afford a new way of exploring the inter-relationships of the members of a group, concerning which most divergent opinions have been held.

Experimental.

I. Preparation and analyses of the salts.

The chlorides, bromides, and iodides of rubidium and caesium were mostly purchased from Merck, small quantities of some of them being also made by double decomposition of the metallic sulphate and the halogen salt of barium. Potassium and barium cyanides were purchased from Kahlbaum, and, setting out from the latter, rubidium and caesium cyanides were made by double decomposition. The remaining salts were the chemically pure salts of commerce. Several attempts were made to bring ammonium cyanide into the scope of this inquiry, but were unsuccessful owing to the instability of this compound. The cyanides of caesium and sodium were prepared, but it was found impossible to use them, owing to the difficulties encountered in obtaining good crystals.

Sodium bromide and iodide crystallize with two molecules of water at ordinary temperatures in monoclinic plates, but at higher temperatures anhydrous cubes are formed. It was found possible to isolate cubes of sodium bromide of sufficient size above a temperature of 60° C., so the growths on these cubes were investigated. Anhydrous cubes of sodium iodide are more difficult to obtain, a higher temperature being necessary, and they are difficult to isolate owing to their great deliquescence; on this account it was found impossible to use them in the experiments on parallel growths. Sodium cyanide crystallizes at ordinary temperatures

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in monoclinic plates—apparently isomorphous with the hydrated bromide and iodide—which are probably the compound $NaCN . 2H_2O$ obtained by Joannis [1] from an alcoholic solution. At slightly higher temperatures, anhydrous cubes are formed. Sodium chloride separates out in monoclinic plates with two molecules of water below $-10°$ C. (Mitscherlich). We therefore see that all the four sodium salts appear in two modifications, one anhydrous at higher temperatures, the other hydrated at lower temperatures; the transition temperatures approximately lie at $-10°$ C. for sodium chloride, 50° C. for sodium bromide, 65° C. for sodium iodide, and 30°.C. for sodium cyanide.

The analysis of rubidium cyanide consisted in a cyanogen determination by precipitation with silver nitrate, the silver cyanide being dried and weighed—

0·4555 gram gave 0·4799 gram AgCN; CN = 23·00 per cent.
(RbCN requires 23·37 per cent.)

The specific gravities of potassium and rubidium cyanides were determined by the suspension method, the suspension fluid employed being a mixture of methylene iodide and benzene; only the clearest splinters were used.

Potassium cyanide: two determinations with independent material gave a mean value

Sp. gr. (17°/4° C.) = 1·578.

Rubidium cyanide: three determinations gave a mean value

Sp. gr. (21°/4° C.) = 2·295.

Determinations of the solubility of potassium cyanide and the specific gravity of the solution were made—

100 parts water dissolve 81·3 parts KCN at 13° C., and the specific gravity of the saturated solution is

Sp. gr. (13°/4° C.) = 1·2220.

II. Crystalline form and habit of the salts.

Some of the salts yield fine, clear cubes from the pure aqueous solution, while others can only be obtained in clear crystals by the addition of other substances to the solution. The following is an account of the various salts:—

Sodium chloride.—Cubes of a sufficient size are difficult to obtain, so most of the experiments on parallel growths were made with rock-salt

[1] Ann. Chim. Phys. 1882, ser. 5, vol. xxvi, p. 484.

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from Galicia. Retgers[1] obtained good cubes by the addition of various substances to the solution, e.g., K_2CO_3, HCl, $FeCl_3$, $CuCl_2$, NaOH, &c.; the author found the last of these to give the best results.

Potassium chloride.—This tends to form skeletal growths, but good crystals were obtained from solutions containing 1 per cent. of KOH.

Potassium bromide and iodide; ammonium iodide; rubidium chloride, bromide, and iodide; potassium and rubidium cyanides; sodium bromide (above 60° C.).—The pure solutions of all these salts gave good cubes.

Ammonium chloride and bromide crystallize in skeletal forms, which are combinations of {211} and {110} (Tschermak, Slavík). Retgers (loc. cit.) showed that the presence of urea—which induces an octahedral habit in sodium chloride—favours the formation of simple cubes. These observations were repeated by Krickmeyer[2], who failed to obtain good cubes of ammonium bromide. The author finds that far more urea is required with ammonium bromide than with ammonium chloride; in fact the solution must contain great excess of urea, and by this precaution large cubic crystals of a yellowish tinge are obtainable by slow evaporation over sulphuric acid. The cubes of ammonium chloride attain a considerable size — up to 8 cubic centimetres; the crystals of ammonium bromide are somewhat smaller. Analyses were made in order to see whether the crystals contain urea:—

0·1931 gram AmCl gave 0·5160 gram AgCl, corresponding to 99·75 per cent. AmCl.

0·2400 gram AmBr gave 0·4562 gram AgBr, corresponding to 99·18 per cent. AmBr.

Since the crystals contained many inclusions of the mother-liquor, the above analyses prove that the crystalline material is practically free from urea; the crystals are very tough and the cubic cleavage is very imperfectly developed.

Although Sprockhoff[3] obtained good crystals of the caesium salts, the author has not been able to get large enough crystals for the study of parallel growths, so that the caesium salts have only been used as solutes.

III. Volume constants.

The halogen salts have been repeatedly investigated, and quite recently they have been the subject of an elaborate research by Sprockhoff (loc.

[1] Zeits. physik. Chem., 1892, vol. ix, p. 267.
[2] Zeits. physik. Chem., 1896, vol. xxi, p. 71.
[3] Neues Jahrb. Min., 1904, Beilage-Band xvi, p. 121.

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cit.), so that it was not necessary to make any specific gravity determinations. Below is a table giving the molecular weight, specific gravity, and molecular volume of all the substances used in this investigation. The sources of the values of the specific gravities are given in brackets, and the atomic weights are those recommended by the International Committee for 1906, O = 16.

Table of Volume Constants.

Salt.	Molec. wt.	Sp. gr.	Molec. vol.
NaCl	58·50	2·173 (Gossner)[1]	26·92
NaBr	103·01	3·198 (Favre and Valson)[2]	32·21
NaI	150·02	3·654 („ „)	41·06
KCl	74·60	1·990 (Sprockhoff)[3]	37·49
KBr	119·11	2·751 („)	43·30
KI	166·12	3·131 („)	53·06
KCN	65·19	1·578 (Barker)	41·31
RbCl	120·95	2·806 (Sprockhoff)	43·10
RbBr	165·46	3·356 („)	49·30
RbI	212·47	3·564 („)	59·62
RbCN	111·54	2·295 (Barker)	48·60
CsCl	168·35	3·994 (Sprockhoff)	42·15
CsBr	212·86	4·452 („)	47·81
CsI	259·87	4·539 („)	57·25
AmCl	53·52	1·531 (Gossner)	34·96
AmBr	98·03	2·256 (Slavík)[4]	43·45
AmI	145·04	2·501 („)	58·14

The specific gravity determinations of the rubidium and caesium haloids made by Setterberg[5] agree well with the above values of Sprockhoff.

IV. Experiments on parallel growth.

The method of observation was extremely simple; a drop of a solution of one salt was placed on a fresh cleavage-piece of the other, which was viewed—on a glass-slide—under the microscope. Crystals of the solute appear as a rule in a few seconds, but the deposition is sometimes so rapid that the surface of the cleavage-flake becomes opaque instan-

[1] Gossner, Zeits. Kryst. Min., 1903, vol. xl, p. 70.
[2] Favre and Valson, Compt. rend. Acad. Sci. Paris, 1873, vol. lxxvii, p. 579.
[3] Sprockhoff, loc. cit.
[4] Slavík, Zeits. Kryst. Min., 1902, vol. xxxvi, p. 271.
[5] Öfvers. k. Vet.-Akad. Förh. Stockholm, 1882, vol. vi, p. 23.

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taneously; when this happened the solution was diluted a little, but even then, with certain pairs of salts, the deposition was so dense as to prevent the attainment of a positive result. Another difficulty also arises where the solubility is far greater for the crystal than for the solute, because the crystal then dissolves rapidly and the crystals deposited by the solute stream down the sides of the 'mother-crystal' and come to rest on the glass-slide.

Sometimes the cleavage-piece was heated while the deposition was going on. By varying the conditions of experiment, definite conclusions were finally arrived at with the great majority of the possible pairs of substances.

The following is a detailed account of the experiments:—

Sodium Chloride.—The material used was rock-salt from Galicia; it contained many fluid-inclusions in the form of negative crystals.

KCl gave opaque cubes with somewhat imperfect outlines; KBr, KI, and KCN crystallized out in cubes with sharp outlines; RbCN in flowery cubes—the deposition of all these salts being parallel with the rock-salt. RbCl deposited crystals very similar to those of KCl, which were often parallel, but generally irregular[1]; many attempts were made to decide one way or the other, but unsuccessfully. As the growths of sodium chloride on RbCl are parallel, it may be concluded that the deposition of RbCl on NaCl is really parallel. None of the remaining salts—except NaBr and NaI which are hereafter mentioned in a separate sub-section—gave a regularly orientated deposition: of these RbBr, RbI, AmI, AmCl, and AmBr, from solutions containing urea, gave well-defined cubes; CsCl and CsBr gave petal-like forms; CsI, AmCl, and AmBr, from their pure solutions, yielded rods.

Sodium Bromide.—Cubes were obtained from aqueous solution above 60° C.

KI, RbI, RbBr, and RbCl gave beautiful parallel cubes, as did also probably CsCl, but it is impossible to say with certainty owing to the rapidity of the deposition; the character of the deposition of KCN, RbCN, AmI, and CsBr could not be made out for the same reason. Streams were immediately set up with NaCl, KCl, KBr, AmCl, and AmBr; CsI gave irregular growths of cubes and dodecahedra.

Potassium Chloride.—The crystals were obtained from a solution containing a little potash.

[1] The term *irregular* does not mean that the outlines of the crystal were ill-defined, nor does it mean that the crystals do not belong to the regular system; throughout this paper it is consistently used to denote *not parallel*.

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NaCl gave cubes traversed by two diagonal bands: they are apparently made up of an immense number of small parallel cubes; KBr, RbCl, RbBr, KCN, and RbCN gave fine cubes: all the above were parallel. AmBr, with or without the addition of urea, gave a zonal growth or layer-crystal (Schichtkrystall): in other words the solution evaporates away without the formation of any separate, visible crystals in parallel position, but an even layer of crystalline material is spread over the whole cleavage-surface of the mother-crystal. (For a discussion of zonal growths see p. 252.) The remaining salts crystallized in the characteristic forms noted above under sodium chloride, but without any recognizable regularity.

Potassium Bromide.—Crystals were obtained from pure aqueous solution.

NaCl, KCl, and AmI immediately gave dense deposits of parallel cubes; the crystallization was slower with KI, RbBr, RbI, and RbCN, which yielded beautiful cubes in parallel position. But, in addition, AmCl and CsCl, which usually crystallize in rods or fronds, came down in parallel cubes. A zonal growth was afforded by KCN and RbCl, but on warming the latter slightly delicately fine, parallel cubes were obtained. The remaining salts were irregularly orientated: CsCl crystallized in petals; CsI in rods and dodecahedra.

Potassium Iodide.—Cubes were obtained from aqueous solution.

Parallel deposits of cubes were obtained with NaCl, RbCl, RbBr, AmCl, AmBr, KCN, KBr, and RbI, the two last salts coming down copiously. Nothing definite could be arrived at with KCl, owing to the rapid dissolution of the mother-crystal with subsequent streaming. AmI did not produce any separate crystals, but a zonal growth was formed. CsCl, CsBr, and CsI crystallized irregularly in rods.

Potassium Cyanide.—Obtained as cubes by slowly cooling a hot, aqueous solution.

KI and AmI gave parallel cubes; KCl gave a fine deposit, but parallel cubes grew out from the sides of the crystal, whilst RbCl formed a zonal growth. Dense deposits were immediately given by NaCl, KBr, AmCl, AmBr, CsCl, and CsBr, which excluded further investigation; RbCN gave some parallel cubes on heating. With RbBr the deposition, even with dilute solutions, was too rapid to enable one to judge whether it was parallel or no; finally CsI gave irregular rods.

Rubidium Chloride.—Obtained as cubes from aqueous solution.

Parallel deposits of cubes were afforded by CsBr and RbCN, and also, as a rule, by NaCl, whilst RbI and AmI gave cubes in irregular positions.

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A zonal growth was formed with KBr and with KCN, but the latter gave a parallel deposition of cubes on heating; nothing could be deduced from the growth of KCl, KI, and RbBr owing to the rapid precipitation. AmCl and AmBr crystallized in irregular positions, in cubes or fronds, according as urea was present or absent; CsCl yielded irregular petals, and CsI, on heating, irregular rods.

Rubidium Bromide.—Obtained as cubes from aqueous solution.

Parallel cubes were deposited from solutions of KI, RbI, AmI, KCl, KBr, and RbCl, and the deposition of the three last salts was particularly dense; the cubes of NaCl, on the other hand, were irregular. The floral crystals of CsCl, and the rods of CsBr, CsI, and AmBr, together with the fronds of AmCl, had no definite orientation. A very finely divided deposit was given by KCN, but RbCN afforded a zonal growth.

Rubidium Iodide.—Obtained as cubes from aqueous solution.

Parallel cubes were obtained with KBr, RbBr, and with AmBr, even in absence of urea, whilst AmCl gave irregular growths; parallel deposits of a semi-zonal character were obtained with KI and AmI, but irregular rods were deposited from solutions of CsCl, CsBr, and CsI. Nothing could be made out with regard to NaCl, KCl, and RbCl, owing to the streaming set up. Copious precipitation immediately occurred on contact with solutions of KCN and RbCN, and of these it can only be said with certainty that the former salt was parallel.

Rubidium Cyanide.—Obtained as cubes from aqueous solution.

KCl, KBr, KI, RbCl, RbI, and AmI gave parallel cubes, the deposition as a rule being copious; RbBr gave a zonal growth, but, on heating, parallel cubes. The deposition was so rapid with NaCl, AmCl, AmBr, CsCl, and CsBr that its nature could not be made out; CsI gave irregular rods, and, finally, streaming occurred with KCN.

Ammonium Chloride.—Cubes were obtained from an aqueous solution containing urea.

The following salts gave irregular deposits of cubes: NaCl, KCl, KBr, KI, KCN, RbCl, RbBr, RbI, AmI, and (probably) RbCN; whilst parallel deposits of cubes ensued with AmBr (with or without urea), CsCl, and CsBr. CsI, on the other hand, gave irregularly orientated rods.

Ammonium Bromide.—Cubes were obtained from an aqueous solution containing great excess of urea.

Floral cubes in irregular positions were obtained from solutions of KBr, KI, KCN, RbCl, RbBr, RbI, RbCN, and AmI; whilst NaCl, KCl, and AmCl yielded parallel cubes. Parallel depositions, taking the form of 4-petal groups, were derived from CsCl and CsBr; a very finely divided

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deposit was afforded by CsI, the character of which could not be made out.

Ammonium Iodide.—Obtained as cubes from aqueous solution.

CsCl, CsBr, and AmBr gave rods; NaCl and AmCl (with urea), cubes; CsI, petals—all irregularly orientated. KCN gave a very thick deposit, which was finally made out to consist of parallel cubes. The precipitation of the other salts—KCl, KBr, KI, RbCl, RbBr, RbI, and RbCN—was too dense for the determination of the nature of the growth.

V. Behaviour of solutions of sodium bromide and iodide.

Sodium bromide is deposited from its aqueous solution on rock-salt in the monoclinic form—$NaBr.2H_2O$—in irregular position, but, on heating, anhydrous parallel cubes come out. Parallel deposits of isotropic cubes (presumably anhydrous) are also immediately formed even in the cold on crystals of KCl, RbCl, KI, and RbI; and a very copious precipitate obtains with AmI and AmCl (parallel?), whilst with KBr, RbBr, and AmBr no cubic crystals seem to come out (it is of course possible that a zonal growth is partly formed, though not to be expected); but on allowing to stand in a desiccator, birefringent crystals (hydrated) are deposited. If, however, the temperature is above 50° C. parallel growths of isotropic cubes are obtained. The character of the growths on KCN and RbCN could not be made out, a thick deposit being immediately formed.

It will be observed from the above that isotropic cubes only appear immediately, where there are four variables or ions: e.g., NaBr on KCl; whilst no cubes—but in time hydrated salts—appear, where three variables are present: e.g., NaBr on NaCl. The same inexplicable behaviour is met with on turning to sodium iodide: here, parallel growths of isotropic cubes are immediately obtained on crystals of KBr, RbBr, KCl, and KCN; the deposition is too rapid with RbCl, but with AmCl and AmBr the cubes deposited are irregular. No cubic crystals have been observed to appear on crystals of NaCl, KI, RbI, and AmI—where there are only three variables; but, on heating, isotropic cubes, apparently parallel, are obtained on KI, RbI, and AmI. The nature of the growth of NaI on RbCN could not be made out.

Theoretical.

I. Discussion of the inter-relationships of the salts.

Although all the seventeen salts used in the above experiments crystallize in the same system and are of analogous chemical composition,

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there is, nevertheless, considerable doubt whether they can be regarded as isomorphous in the strictest sense of the term. At the outset, sodium salts are rarely, if ever, isomorphous with the corresponding potassium, rubidium, and caesium salts, except in very complex molecules, where it is also generally found that substitution even by hydrogen does not alter the crystalline form; moreover, much evidence has been accumulated by different observers indicating that it is not permissible to regard the remaining salts as constituting a single isostructural group: upon this point, all authors are in agreement. But, how the group is to be subdivided, and what are the relationships of these sub-groups to each other, are questions difficult to decide and conducive to much controversy. It would be superfluous to give an historical summary of the views hitherto held. The following are the author's views: and it is only just to say that they are almost wholly based on the work and opinions of others.

The group must be divided into two sub-groups, which are hereafter called *A* and *B* respectively: the members of each sub-group are at least isostructural and possibly isomorphous in the strictest sense. Groups *A* and *B*, on the other hand, are not isostructural with each other; but a salt belonging to group *A* may mix with a salt of group *B* in restricted proportions, each salt taking up a little of the other, the salt taken up assuming the (labile) structure of the other: in other words the two sub-groups are isodimorphous. The classification is as follows:—

Group *A*.—NaCl, NaBr, NaI, KCl, KBr, KI, KCN, RbCl, RbBr, RbI, RbCN, AmI (and probably NaCN).

Group *B*.—AmCl, AmBr, CsCl, CsBr, CsI (and probably CsCN).

The following are the reasons for this classification:—

1. *Considerations of Molecular Volume.*

It has been shown by Tutton, as also by Muthmann and others, that the replacement of an atom of potassium by one of rubidium, or the latter by one of caesium, is accompanied by a fairly regular increase in molecular volume: this holds for all the salts investigated by Tutton (with the exception of ammonium selenate), namely, the simple and double sulphates and selenates, also for the permanganates (Muthmann) and the perchlorates; moreover, the molecular volumes of the ammonium salts approximate very closely to those of the rubidium salts—sometimes they are a little greater, sometimes a little less.

Now in the above cubic group of salts, the increase in molecular

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volume in passing from a potassium to the corresponding rubidium salt regularly amounts to about 5–6 units; but on turning from a rubidium to a caesium salt one actually finds a decrease in molecular volume. Again the molecular volumes of ammonium chloride and bromide are abnormally low—even less than those of potassium chloride and bromide, whilst ammonium iodide has a normal value, being nearly equal to that of rubidium iodide.

The above irregularities disappear if the group is split up into two parts—groups *A* and *B*—the members of group *A* having relatively greater molecular volumes.

Division into groups A and B.

Group *A*.—NaCl, 26·92	(NaCN, ?)	NaBr, 32·21	NaI, 41·06
KCl, 37·49	KCN, 41·31	KBr, 43·30	KI, 53·06
RbCl, 43·10	RbCN, 48·60	RbBr, 49·30	RbI, 59·62
Group *B*.—AmCl, 34·96	(AmCN, ?)	AmBr, 43·45	AmI, 58·14
CsCl, 42·15	(CsCN, ?)	CsBr, 47·81	CsI, 57·25

A glance at the above table is sufficient to show that each sub-group exhibits regularities in molecular volumes comparable with those met with in the groups investigated by Tutton.

The sodium salts are placed in group *A* because they possess lower molecular volumes than the potassium salts; this would be expected from the position of sodium in the periodic classification, provided all the salts belong to the same isostructural group.[1]

That the sodium salts all belong to one group, in contradistinction to the ammonium salts, is conclusively proved by the absence of any sudden jump in passing from one to another.

The cyanides of potassium and rubidium are placed in group *A*, though it might seem arbitrarily. Considerable difficulties have been met with in the investigation of caesium cyanide, and this is unfortunate, for a

[1] It is worthy of note that the difference in molecular volume of the sodium and potassium salts is about twice the corresponding difference between the potassium and rubidium salts, and it may possibly be argued from this that the sodium salts ought to form a further sub-section of group *A*; still another argument in favour of this is found in the total non-miscibility of sodium chloride and potassium chloride (Krickmeyer, loc cit.). On the other hand, since the molecular volumes of the sodium salts are so low, it might be inferred that they ought to belong to group *B*; but, as will be seen later, the good cubic cleavage and, more especially, the experiments on parallel growth effectually negative this alternative.

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knowledge of the molecular volume of caesium cyanide—if it proved to be lower than that of rubidium cyanide—would furnish fairly conclusive evidence for placing rubidium and potassium cyanides in group *A*, and caesium cyanide itself in group *B*. But, as will be seen later, the results of the experiments on parallel growths furnish evidence of a trustworthy character for the correctness of the above position. The elusive nature of ammonium cyanide prevented its employment in this research. It is a remarkable fact that the volume occupied by the cyanogen radical—consisting of two atoms—is about equal to the volume occupied by an atom of bromine, but less than that of an atom of iodine. This is a similar result to that derived by Tutton with respect to the volume of the ammonium radical—consisting of five atoms—compared with the volumes of the metallic atoms, rubidium and caesium. One of the contributory causes is, of course, the low molecular weight of these two radicals.

2. *Considerations of Form and Cleavage.*

The characteristic crystalline form of the members of group *A* is without exception the simple cube (sometimes octahedral facets are present); moreover, there is a perfect cubic cleavage with all the members. The cube, however, is quite a subordinate form with salts in group *B*: ammonium chloride and bromide crystallize in feathery groups which are probably combinations of {211} and {110}; caesium chloride, generally in the same form, but also in dodecahedra and cubes; caesium bromide, in dodecahedra which are as a rule elongated along a trigonal axis (Sprockhoff); and caesium iodide, in dodecahedra.

As mentioned above, ammonium chloride and bromide can be obtained in large cubes by the addition of urea to the solution, but the cubic cleavage is very imperfectly developed. The caesium haloid salts nevertheless, according to Sprockhoff, exhibit a good cubic cleavage.

3. *Considerations of Miscibility.*

The evidence derived from the degree of miscibility of pairs of salts is generally in favour of the above classification: the members of group *A* mix better with each other than do those of *A* with those of *B*. The miscibility of members of group *B* with each other has, unfortunately, not been investigated.

Below is given a list of those miscibilities which have been hitherto determined:—

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(i) Members of group *A* with each other.

AmI and KI in all proportions (Gossner)[1].
KCl and KBr almost totally miscible (Fock)[2].
KI takes up 30 per cent. KBr (Fock). [(Gossner).
KCl with KI, there is a gap, not determined quantitatively

(ii) Members of group *A* with group *B*.

18 per cent. AmCl—3 per cent. KCl (Fock).
40 „ „ AmBr—1½ „ „ KBr (Fock).
AmCl with AmI, large gap (Gossner).
NaCl and AmCl do not mix at all (Krickmeyer).

Perhaps the force of this evidence is weakened by the fact that sodium chloride and potassium chloride do not mix at all, although they both belong to group *A* (see footnote on p. 245).

4. *Considerations of Parallel Growth.*

The results of the experiments on parallel growth decidedly point to the above classification: as a rule, members of group *A* form parallel growths on each other, and the same holds for members of group *B* *inter se*; while members of group *A* on group *B* (or group *B* on group *A*) almost always yield growths which are irregular.

It must be stated that the evidence derived from etching is not in agreement with the above classification: thus, AmCl (Tschermak); KCl (Brauns); KBr, RbCl, RbBr, and CsBr (Sprockhoff) all belong to the tesseral-holoaxial or gyrohedric-hemihedral class of the cubic system. But KI, CsCl, and CsI (Sprockhoff) as well as NaCl (Brauns) belong to the holohedral class.[3] It will thus be seen that a classification based on symmetry, as derived by etching, only succeeds in separating salts which otherwise resemble each other, just as well as it brings together salts which have the least analogies of all.

The author believes that the above considerations are strongly in favour of the classification here adopted. Whether each sub-group is further divisible or no can only be decided when evidence, much more

[1] Zeits. Kryst. Min., 1905, vol. xl, p. 69.

[2] Zeits. Kryst. Min., 1897, vol. xxviii, p. 351.

[3] The symmetry of a crystal, as derived from etching figures, does not necessarily give the real symmetry; for the latter, although it cannot be higher, may nevertheless be lower than the former. Hence, it is not absolutely excluded that the real symmetry of the above compounds is the same, and possibly even lower than the symmetry exemplified by the tesseral-holoaxial class.

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than is at present available, has been accumulated. The experiments on parallel growth do not furnish any evidence, for or against, in this direction.

It is interesting to note that direct evidence for the isodimorphism of ammonium chloride has been produced by Lehmann[1], who observed that feathery cubes separate from hot solutions which, on contact with the ordinary rod-modification, were transformed into the latter. Again, from an aqueous solution containing a little cadmium chloride, rounded cubes were obtained which on standing 'explode' into skeletal crystals.

More reliable evidence would be obtainable from a careful determination of the specific gravities of the isomorphous mixtures given by ammonium and potassium bromides, for if the specific gravity of the labile modification of ammonium bromide, taken up by the potassium bromide, were found different from (and probably less than) the specific gravity of the ordinary modification, we should have direct and conclusive evidence of isodimorphism.

II. Connexion between Parallel Growth and Molecular Volume.

The results of the experiments on parallel growths are collected in the accompanying table in which the members of group *A* are followed by those of group *B*; the salts in each group are arranged in order of molecular volume. The table is divided up by means of heavy lines into four areas corresponding to the growths of the following salts:—(1) *A* on *A*, (2) *B* on *A*, (3) *A* on *B*, and (4) *B* on *B*.

The method of construction of the table is best illustrated by taking an example. In the vertical column headed by KBr and horizontally opposite to RbCN there is a letter P; this denotes that the growth of crystals (deposited from a solution) of KBr on a crystal of RbCN is parallel; similarly, under the column headed RbCN and horizontally opposite to KBr the letter P again denotes that the growth of crystals (deposited from a solution) of RbCN on a crystal of KBr is parallel. Ir denotes that a growth was irregular (not parallel), and Z that a (parallel) zonal growth is obtained. For the signification of the letters placed in brackets see below, under 'Members of group *A* on each other'. From the method of construction of this table, it is obvious that, the less the difference between the molecular volumes of two

[1] Zeits. K[illegible] M[illegible] 1885, vol. x, p. 821.

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salts, the closer will the squares, which represent the growths in the table, approximate to the diagonal line drawn from the top left hand to the bottom right hand corner.

Results of Experiments on Parallel Growth.

Members of Group *A* on each other. Group *B* on Group *A*.

Mol. Vol.	26·92	32·21	37·49	41·06	41·81	43·10	43·80	48·60	49·30	53·06	58·14	59·62	34·96	42·15	43·45	47·81	57·25
	NaCl	NaBr	KCl	NaI	KCN	RbCl	KBr	RbCN	RbBr	KI	AmI	RbI	AmCl	CsCl	AmBr	CsBr	CsI
NaCl		P	P	P?	P	P	P	P	Ir	P	Ir	Ir	Ir	Ir	Ir	Ir	Ir
NaBr	(P)		(P)	P	?	P	(P)	?	P	P	?	P	?	P?	?	?	Ir
KCl	P	P		P	P	P	P	P	P	Ir	Ir	Ir	Ir	Ir	P	Ir	Ir
NaI	(P)	(P)	(P)		(P)	(P)	(P)	?	(P)	(P)	(P)	?	?	?	?	?	?
KCN	(P)	?	P	P		Z	Z	P	?	P	P	(P)	?	?	?	?	Ir
RbCl	P	P	(P)	P?	Z		Z	P	(P)	(P)	Ir	Ir	Ir	Ir	Ir	Ir	Ir
KBr	P	P	P	P	Z	Z		P	P	P	P	P	P	P	P	Ir	Ir
RbCN	(P)	?	P	?	(P)	P	P		Z	P	P	P	?	?	?	?	Ir
RbBr	Ir	P	P	P	?	P	P	Z		P	P	P	Ir	Ir	Ir	Ir	Ir
KI	P	P	Ir	P	P	P	P	P	P		Z	P	P	Ir	P	Ir	Ir
AmI	Ir	?	(Ir)	P	P	(Ir)	(P)	(P)	(P)	(Z)		Z	Ir	Ir	Ir	Ir	Ir
RbI	Ir	P	Ir	?	P	Ir	P	(P)	P	Z?	Z		Ir	Ir	P	Ir	Ir
AmCl	Ir	?	Ir	Ir	Ir	Ir	Ir	Ir	Ir	Ir	Ir	Ir		P	P	P	Ir
CsCl	?	?	?	?	?	?	?	?	?	?	?	?	(P)		(P)	?	?
AmBr	P	P	P	Ir	Ir	Ir	Ir	Ir	Ir	Ir	Ir	Ir	P	P		P	?

Group *A* on Group *B*. Group *B* on each other.

(P = parallel growth; Ir = irregular (non-parallel) growth; Z = zonal growth.)

The discussion may be conveniently divided into three parts corresponding respectively to growths where

(1) both salts belong to group *A*,

(2) both salts belong to group *B*, and

(3) one salt belongs to *A* and the other to *B*.

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1. *Members of group A on each other.*

It is obvious that with each pair of substances we have two cases, namely, salt (1) on salt (2), and salt (2) on salt (1); and whenever it was possible to come to a definite conclusion, it was always found that the growths were either both parallel or both irregular: e.g., both KCl on NaCl, and NaCl on KCl gave parallel growths, but RbBr on NaCl and NaCl on RbBr both afforded irregular deposits. This is, of course, what one would expect.

Now, as mentioned above, with certain pairs of salts it was only possible to determine the character of the growth in one direction: e.g., RbCl on RbBr was made out to be parallel, but the deposition of RbBr on RbCl was too rapid to enable one to decide whether it was parallel or no. The fact that a parallel growth is obtained one way is strong evidence for believing that the same is really obtained the other way, and, in order to make the table as complete as possible, the letter P is placed in brackets; the same remarks hold for (Ir). Finally, in a few instances, the nature of the parallel growth could not be determined either way, and notes of interrogation are then placed in the table.

This isostructural group is big enough, and only just big enough, to show that parallel growths are conditioned by a similarity of molecular volume, or perhaps it were better to say that irregular growths are only met with where the molecular volumes differ considerably.

It is seen from the table that the irregular growths are all grouped in the top right hand and the bottom left hand parts of the diagram, and the line of demarcation is essentially, though not perfectly, indicated by the double line: the parts thereby cut off are chiefly occupied by irregular growths and the rest of the field is wholly taken up with the parallel growths.

The parallel growths met with in the two 'irregular regions' are those in which the salts NaBr and NaI are concerned, and it was pointed out in the experimental part of this memoir that the behaviour of these salts is in many other respects of an equally inexplicable character, so that a further investigation is desirable. For a discussion of zonal growths see p. 252.

2. *Members of group B on each other.*

Owing to the difficulties encountered in obtaining crystals of a sufficient size of the salts CsCl, CsBr, and CsI, we are here restricted to the

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growths on cubes of AmCl and AmBr crystallized from solutions containing urea. But the results, as far as they admit of interpretation, point in no less degree to the importance of similarity of molecular volume in conditioning a parallel growth; this is immediately seen from the fact that, of the four salts AmBr, CsCl, CsBr, and CsI, the last is the only one to give irregular growths on crystals of AmCl. Unfortunately, the character of the growth of CsI on AmBr could not be definitely determined owing to the fineness of the deposit: the latter may be possibly consequent on the formation of a parallel growth, but this, of course, is by no means necessary.

3. *Members of group A on those of group B, and vice versa.*

It will be seen from the table that as a rule the growths are here irregular, which is an indication that these pairs of salts are not isostructural. But in some nine cases (possibly ten) parallel growths are obtained and they are tabulated below:—

KCl, 37·49 / AmBr, 43·45	CsCl, 42·15 / KBr, 43·30	CsCl, 42·15 / NaBr, 32·21 } ?	NaBr, 32·21 / AmBr, 43·45
KBr, 43·30 / AmCl, 34·96	KI, 53·06 / AmBr, 43·45	RbI, 59·62 / AmBr, 43·45	NaCl, 26·92 / AmBr, 43·45
	KBr, 43·30 / AmBr, 43·45	KI, 53·06 / AmCl, 34·96	

With the first pair, parallel growths of a semi-zonal character are obtained, no matter which salt is the solute; the next three pairs could only be investigated in one direction: the second and third with the salt of group *B*, the fourth with the salt of group *A*, as solute. But the remaining six pairs only yielded parallel growths when the salt of group *A* was used as the crystal, the salt of group *B* being the solute; if crystals of group *B* were taken, and solutes of group *A*, then the growths obtained were irregular. This can hardly be caused by the roughness of the surface (owing to the imperfect cleavage) in the salts of group *B*, for, as mentioned above, KCl does give a parallel growth on AmBr.

It will be noted that the difference between the molecular volumes in certain of these pairs is considerable, while many other pairs, which fail to give parallel growths, exhibit far closer molecular volumes. Is it possible that the cubes of AmCl and AmBr, deposited in parallel position on the salts of group *A*, are crystals of the labile (group *A*) forms of AmCl and AmBr?; for the molecular volumes of labile AmCl

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and AmBr would be about 42 and 48 respectively, and the differences between these numbers and the molecular volumes of the salts on which they were deposited would be very small, and therefore parallel growths would be expected (the crystals being isostructural). On the other hand, a crystal of AmCl or AmBr may not be able to force a salt of group *A* to take up the labile (group *B*) form; and hence parallel growths may not be formed. This is a hypothesis which can be proved or disproved by a study of parallel growths of isodimorphous pairs of substances, which crystallize in two different systems: and the author hopes to attack this problem in the near future.

4. *Zonal Growths.*

With some of the pairs of substances investigated, separate discernible crystals of the solute are not formed on the mother-crystal, but, as the solution evaporates away, the solute is evenly deposited on the whole of the surface; a zonal growth (Schichtkrystall) is thereby formed. Under a high magnification, a fine network of lines is often visible parallel to the cube-edges. It was previously shown by the author (loc. cit.) that this behaviour is characteristic of isostructural substances, the molecular volumes of which are practically identical; and it is satisfactory to note that the present work is in complete accord with that generalization.

It is seen from the table that the zonal growths lie close to the long diagonal running from the top left hand to the bottom right hand corner, which is the line expressing equality of molecular volume.

Now, as pointed out on p. 243, no separate crystals appear when, say, a drop of a solution of NaBr is placed on a crystal of RbBr, and yet the molecular volumes of these salts are greatly different. But on forcing the crystallization by heating, a most beautiful and copious formation of parallel cubes obtains. On the other hand, with the true zonal growths very few, if any, separate cubes (in parallel position) appear: the solute is deposited, partly in an even manner on the whole of the surface, and partly in ridges which often have crystallographic outlines parallel to those of the mother-crystal. This behaviour was especially observed with the alums, which possess almost identical molecular volumes, and with solutions of ammonium or thallium perchlorate on crystals of rubidium perchlorate. When a crystal of potash-alum and a solution of ammonia-alum are employed, a ridge, hexagonal or triangular in outline, is gradually formed round the edges of the upper surface of the crystal, and many drops of solution may be successively

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added and evaporated away by heat, without the separation of separate octahedra. Again, with rubidium perchlorate, the polarization-tint gradually alters owing to the thickening of the crystal by the even deposition of a layer of thallium or ammonium perchlorate.

III. Interpretation of Parallel Growths in terms of Topic Axes.

The simplest assumption one can make with regard to parallel growths is that they are brought about by a fitting together of similar structures. And it has been shown that in the above two isostructural sub-groups, as well as in the two isostructural groups previously studied by the author (the calcite-sodium-nitrate and the barytes-perchlorate groups), parallel growths are conditioned by similarity of molecular volume. Now, by combining the molecular volume with the axial ratios in a simple way, the distances between adjacent particles of the crystal structure may be calculated; these distances are known as topic axes. Hence, if parallel growths result from the close fitting of two similar structures, it would follow that the topic axes of those pairs of substances which yield such growths should be very close. This was found to be the case with the groups previously studied, and the present investigation affords additional confirmation.

With the salts of group *A*, the similarity of cleavage speaks for a similarity of structure. If, therefore, cleavage cubes of the members of the group be taken of such sizes that their volumes are proportional to the molecular volumes of the substances, their edges may be taken to represent the intervals between the crystal-units spaced along those directions, and are, in fact, the topic axes.

The latter are calculated from the formulae, $\chi = \psi = \omega = \sqrt[3]{V}$, where V = the molecular volume.

Topic Axes of salts of group A.

NaCl, 1·3911	NaBr, 1·4768	KCl, 1·5584	NaI, 1·6013
KCN, 1·6045	RbCl, 1·6274	KBr, 1·6299	RbCN, 1·6939
RbBr, 1·7020	KI, 1·7741	AmI, 1·7981	RbI, 1·8132

Similarly, the different compounds in group *B* can be compared with each other with regard to topic axes, but the topic axes of group *B* cannot be compared with those of group *A*.

Topic Axes of salts of group B.

AmCl, 1·5177	CsCl, 1·6154	AmBr, 1·6318
CsBr, 1·6846	CsI, 1·7889	

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Now, a comparison of the collected results, given in the large table on p. 249, with the above topic axes, will show that, within each isostructural group, irregular growths are only afforded by those pairs of salts the topic axes of which betray considerable differences. In other words, a fitting of the one structure into the other cannot take place when the distances apart of the crystal-units, as given by topic axes, differ greatly.

Addendum.—An important contribution to the theory of crystal-structure has recently been made by Barlow and Pope (Journ. Chem. Soc. Trans., 1906, vol. lxxxix, p. 1675), which seems to point to the possibility of correlating dissimilar structures. In this memoir the authors advance the idea that a crystalline medium results from the close-packing of identical groups of spheres; each group represents a chemical molecule, and is made up of as many spheres as there are atoms in the molecule; further, the volume of each sphere is approximately proportional to the valency of the atom it represents. It must be noted that the absolute volume of an atom of any given element is not necessarily the same in different compounds of that element, but that a dilatation may occur in passing from one compound to another. The sum of the valencies of the constituent atoms is known as the valency volume.

Now, topic axes result from the combination of axial ratios with molecular volumes; if, however, valency volumes are substituted for molecular volumes, a new set of constants, which Barlow and Pope term equivalence parameters, are obtained.

From the above conceptions and by the use of the equivalence parameters, the authors have been able to explain why certain regularities—hitherto unexplained—subsist between the members of a morphotropic group such as that of the humite minerals; and what is even more important, from a consideration of valency volume, they have constructed assemblages of spheres, derived from each other in a simple way, which account for the crystalline form of many aromatic derivatives.

But in their memoir the authors certainly seem to suggest that equivalence parameters possess some advantages over topic axes—even within an isomorphous or, more generally, an isostructural series—and can be employed in place of them.

The writer would remark on this that although valency volumes may be invaluable for certain purposes, yet topic axes are not the less important when comparisons have to be made among the members of an isostructural group. For, although the crystalline structure may be

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deducible from the chemical constitution by means of valency volumes, yet it is only by means of molecular volumes, and therefore of topic axes, that one can compare the relative dilatation of the valency volumes when they unite to form different structures. It is obvious, then, that equivalence parameters do not give the relative magnitudes of the crystal-units of two isostructural substances unless they be further combined with the molecular volumes. Now, since the valency volumes of members of an isostructural group are generally identical, the valency volume may be neglected for purposes of comparison within such a group, and the magnitudes of the crystal-units on Barlow and Pope's theory, or the relative distances between adjacent particles (supposed infinitely small) on the generally received theory, are in reality simply given by the topic axes.

That the consideration of topic axes is indispensable, at any rate within an isostructural group, is proved by the writer's investigations, all of which lead to the conclusion that the possibility of parallel growths can be predicted from a comparison of the topic axes; on the other hand, the following table (p. 256) serves to show that such predictions could not be made from equivalence parameters. The table refers to the isostructural barytes-perchlorate-permanganate group, previously studied by the writer (loc. cit.). Of all the nine soluble salts enumerated, only potassium perchlorate and permanganate form parallel growths on the barytes minerals.

It is seen from the table that, with the exception of the ammonium salts, the equivalence parameters do not show great differences; nor can they be arranged in order of magnitude, for it will be seen that some salts possess a very close x-value to those of the minerals, while others exhibit almost identical y-values. And it would be impossible to foretell from the table which salts should yield parallel growths. A perusal of the topic axes, however (loc. cit.), will show that there is a remarkable relation between similarity of topic axes and formation of parallel growths.

The valency volumes of the halogen salts all possess the same value (namely, 2), with the exception of the ammonium salts, which, together with the cyanides, have the value 8. In the cubic system the equivalence parameters are given by the cube roots of the valency volumes: the equivalence parameters, then, have the values $\sqrt[3]{2}$ or $\sqrt[3]{8} = 1{\cdot}2599$ and 2 respectively, and a consideration of equivalence parameters would lead to erroneous expectations with regard to the formation of parallel growths.

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Equivalence Parameters of the Barytes-Perchlorate-Permanganate Group.

	Val. vol.[1]	x	y	z
Celestine ...	12	2·2457	2·9180	3·6624
Anglesite ...	12	2·2485	2·8636	3·6924
Barytes ...	12	2·2394	2·9381	3·6478
$KClO_4$ ...	10	2·1176	2·7138	3·4749
$KMnO_4$ ...	10	2·1394	2·6835	3·4836
$AmClO_4$ ...	16	2·5050	3·1581	4·0449
$RbClO_4$ ...	10	2·1439	2·6913	3·4662
$AmMnO_4$ ...	16	2·5301	3·0992	4·0810
$TlClO_4$ ...	10	2·1677	2·7171	3·3958
$RbMnO_4$ ...	10	2·1806	2·6238	3·4957
$CsClO_4$ ...	10	2·1776	2·6644	3·4574
$CsMnO_4$ ...	10	2·2242	2·5615	3·5105

Conclusions.

The above work, taken in conjunction with the author's previous investigations, proves that in an isostructural group of substances, irregular growths are only obtained where the molecular volumes differ considerably; and this holds good no matter whether the group consists partly of insoluble minerals and partly of soluble salts, or wholly of soluble salts. But the present memoir especially emphasizes that these conclusions only hold for isostructural substances, and a study of parallel growths will therefore serve to discover whether all the members of a given group are really isostructural.

The investigation of the groups already made does not enable one to predict whether the members of any other isostructural group will all yield parallel growths, because for each group there is a 'crucial difference of molecular volume', which will vary with the group taken; but, when this crucial difference has been determined by a limited number

[1] The values of the valency volumes were derived from the following considerations. Barlow and Pope take S and O as divalent; N, trivalent; and H, Cl, K, Rb, Cs, and Tl monovalent. The writer considers that Ba, Pb, and Sr must be divalent, and has deduced the valency volumes of the permanganates and perchlorates from that of the sulphates by Barlow and Pope's second principle: the replacement of Ba by K necessarily requires a decrease by one in the valency volume of the remaining complex. The valency volume of $KMnO_4$ is therefore 10, and this agrees with the valency volume of $KClO_4$ which must necessarily be 10 since Cl is monovalent. If manganese be taken as divalent ($KMnO_4 = 11$), results are obtained in the equivalence parameters which are at a still greater variance than in the given table.

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of observations, it can confidently be expected that pairs of substances exhibiting a less difference of molecular volume will afford parallel growths.

It is obvious from the present investigation that the crucial difference of molecular volume is a very great one, so that it will not be surprising if no other isostructural group of soluble salts can be found of such a size as to render possible the attainment of *irregular* growths.

The author is greatly indebted to the Chemical Society for defraying the expenses of this research by means of a grant. It is again his pleasant duty to thank Professor H. A. Miers for the valuable advice received during the progress of the research.

Mineralogical Department,
University Museum,
Oxford.

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Ilmenite from Jacupiranga, Brazil.

By G. F. Herbert Smith, M.A., D.Sc., F.G.S.
Assistant in the Mineral Department of the British Museum.

[Read November 13, 1906.]

DURING the summer of this year certain crystals of zirkelite from Ceylon were entrusted to the author for crystallographical investigation, and in that connexion the specimens placed under this species in the British Museum collection were examined for the sake of comparison. The whole of the latter specimens come from Jacupiranga in São Paulo, Brazil: some of them had been presented by Dr. E. Hussak and formed part of the material on which he and Dr. G. T. Prior[1] conducted their investigation which led to the first discovery of zirkelite, while the remainder were purchased subsequently. The latter included a lot of small, brilliant crystals (numbered 86034 in the General Register) which differed so markedly in lustre from the other crystals as to suggest that they had been incorrectly determined. Goniometrical examination leaves no doubt that the crystals are really ilmenite, a mineral already described by Dr. Hussak[2] from the same locality. His crystals have three habits, viz., *cr*, *crn*, and *crsn*.[3]

The crystals examined by the author have also three habits, viz., *cam*, *camrX* (fig. 1), and *cnX* with *r* and *s* small (fig. 2), slightly different

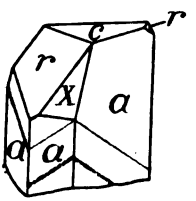

Fig. 1.

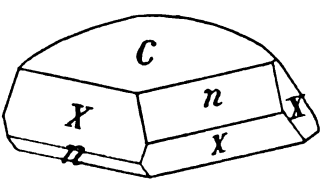

Fig. 2.

Ilmenite from Brazil.

[1] Min. Mag., 1895, vol. xi, pp. 86-88.

[2] Min. Petr. Mitt. (Tschermak), 1895, vol. xiv, p. 407.

[3] The notation adopted in Dana's 'System of Mineralogy,' sixth edition, 1892; and used also by Dr. Hussak.

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from the above. The form $X = (53\bar{1}) = (44\bar{8}3)$ had not been definitely noted on ilmenite until it was found by Mr. R. H. Solly[1] on crystals collected by him in the Binnenthal, Switzerland: on these crystals the form is represented by very small faces, whereas on those from Brazil it is most prominent, particularly in the case of crystals such as that shown in fig. 2. It must, however, not be overlooked that Dr. Hussak[2] described prismatic crystals in which the prism-faces are strongly striated in the horizontal direction and which are terminated by a relatively small basal plane and by a pyramid-form steeply inclined to it. This form is no doubt X, although, as he points out, since there is no form present to determine definitely the orientation, it might possibly be $l = (4\bar{1}\bar{1}) = (50\bar{5}2)$. Further, these crystals give a relatively strong reaction for magnesia, and in minute splinters transmit light of a violet colour.

The present crystals were found by Dr. Prior, using a microchemical test (the precipitation of ammonium-magnesium phosphate), to contain some, but probably only a very small percentage of magnesia. On the other hand, they are opaque, even in the thinnest fragments, and the prism-faces are striated obliquely (cf. fig. 1). The faces of the form a are, indeed, frequently striated parallel to their intersection with the contiguous faces of the form r, and thus reveal the hemihedral type of symmetry characteristic of this mineral; occasionally each face of the form X is also striated parallel to its intersections with the nearest face of the form r.

The measurements made on eight crystals are summarized in the following table:—

Measurements from c = (111) = (0001).

Form.	Calculated[3] Values.	Observed Means.	No.	Limits of Observations.
$r = (100) = (10\bar{1}1)$	57° 58½′	57° 58½′	12	57° 49′–58° 6′
$X = (513) = (44\bar{8}3)$	74 50½	74 49	18	74 25–75 8
$n = (31\bar{1}) = (22\bar{4}3)$	61 33	61 33	5	61 16–61 45
$s = (11\bar{1}) = (02\bar{2}1)$	72 38	72 21	2	72 14, 72 28

[1] Min. Mag., 1906, vol. xiv, pp. 184–186.

[2] Loc. cit., p. 408.

[3] Calculated from the element of N. I. Koksharov, 'Materialien zur Mineralogie Russlands,' 1870, vol. vi, p. 357, which is adopted by Dana, 'System of Mineralogy,' sixth edition, 1892, p. 217.

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The azimuthal readings closely approximated to 30° or 60°. The differences from these values rarely exceeded 2′ in the case of well-defined reflections; 10′ was the maximum noted even in the case of a confused blur. The observed values for *ca* and *cm* approached 90° closely.

The forms *crX* and *n*, and, where present, *a* and *m*, are well developed. The form *s* was only twice observed and in each case the face was minute.

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Note on the thirty-two classes of symmetry.

By Harold Hilton, M.A.
Fellow of Magdalen College, Oxford.

[Communicated by Professor Miers, and read November 13, 1906.]

CONSIDERABLE confusion exists with regard to the nomenclature of the thirty-two possible classes of symmetry and their classification into systems. Each class is usually denoted by a name and a symbol; but as every author invents his own names and symbols (the latter being often merely arbitrary numbers) the whole nomenclature is hopelessly confused. This is due to the fact that a different classification into systems, and consequently a different nomenclature is suggested according as the subject is approached (1) from the geometrical aspect based on the law of rational indices alone, (2) from the aspect of the structure-theory, (3) from the aspect of the practical crystallographer. Thus, for example, Dr. A. Schoenflies [1] finds two distinct classifications necessary according as the subject is approached from aspect (1) or (2).

The question arises whether a simple nomenclature and classification are possible, which will reconcile the differences between the practical and theoretical crystallographer. It is usual to take as fundamental symmetry-elements n-al axes of the first and second sort; where by the former is meant a rotation-axis l such that the crystal is brought to self-coincidence by a rotation through $2\pi \div n$ about l (but through no smaller angle), and by the latter is meant an axis l of rotatory-reflexion (Drehspiegelung) such that the crystal is brought to self-coincidence by a rotation through $2\pi \div n$ about l followed by a reflexion in a plane perpendicular to l. Now we can avoid many difficulties if we define an n-al symmetry-axis of the second sort as an axis l of rotatory-inversion (Drehinversion [2]) such that the crystal is brought to self-coincidence by a rotation through $2\pi \div n$ about l followed by inversion about a point in l. Then any line through a centre of symmetry is a 1-al axis of the

[1] 'Krystallsysteme und Krystallstructur,' 1891, pp. 146 and 148.

[2] As is done by T. Liebisch in his 'Grundriss der physikalischen Krystallographie' (1896), though he does not point out the logical conclusion of his method.

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second sort and a line perpendicular to a symmetry-plane is a 2-al axis of the second sort. An n-al axis of the second sort is equivalent to an n-al rotation-axis plus a centre of symmetry if n is odd, and to an $\frac{1}{2}n$-al rotation-axis plus a perpendicular symmetry-plane if n is even and $\frac{1}{2}n$ odd.

The thirty-two classes will then be grouped naturally into seven systems containing the classes with (1) only 1-al axes (of either sort), (2) one 2-al axis, (3) three perpendicular 2-al axes, (4) a 3-al axis, (5) a 4-al axis, (6) a 6-al axis, (7) more than one n-al axis ($n>2$). These systems coincide exactly with the triclinic, monoclinic, orthorhombic, rhombohedral, tetragonal, hexagonal, and regular systems of the structure-theory and practical crystallography.

As an instance of the simplicity gained by the proposed definition we notice that the same proof of the fact that every n-al symmetry-axis is parallel to a possible edge applies to axes both of the first and second sort ($n=3$ being an exception in both cases).

The classes with a single n-al axis of the first or second sort may be denoted by the symbols C_n and c_n respectively; those with a single n-al axis of the first or second sort and a perpendicular 2-al rotation-axis by D_n and d_n respectively (it is convenient, however, to write C for C_1, D for D_2); and those with an n-al axis of the first sort and a perpendicular 2-al axis of the second sort by δ_n. The tetrahedral and octahedral classes may be denoted by T and O. The addition of a centre of symmetry is conveniently shown by changing C, D, T, O into Γ, Δ, Θ, Ω respectively. These symbols have the advantage of being both simple and descriptive. For comparison they are tabulated below with the corresponding numbers from Professor Miers's 'Mineralogy' (1902, p. 280).

Triclinic	C, Γ	1, 2
Monoclinic	C_2, c_2, Γ_2	4, 3, 5
Orthorhombic	δ_2, D, Δ	7, 6, 8
Rhombohedral	C_3, c_3, δ_3, D_3, Δ_3	9, 15, 12, 10, 19
Tetragonal	C_4, c_4, Γ_4, δ_4, D_4, d_4, Δ_4	21, 22, 24, 25, 23, 26, 27
Hexagonal	C_6, c_6, Γ_6, δ_6, D_6, d_6, Δ_6	14, 11, 17, 18, 16, 13, 20
Regular	T, Θ, θ, O, Ω	28, 30, 31, 29, 32

If the suggestion here thrown out is adopted, all diagrams illustrating crystallographic theory should be drawn on the gnomonic projection. Diametrically opposite points on the sphere of reference are represented by the same point on the plane; the projection of any point being

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marked with a × or a ○ according as the point lies on the half of the sphere nearer to or remote from the plane of projection. Thus the projections of all co-zonal poles lie on one straight line instead of on one or other of two circles as in the usual representation by the stereographic projection. The main objection to the use of the gnomonic projection (namely that the projection cannot be contained within convenient limits) does not apply to illustrative figures; for we may always choose the position of the crystal poles so that the gnomonic diagram occupies a convenient space.

University College,
Bangor, North Wales.

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OBITUARIES.

Samuel Lewis Penfield (1856–1906).

(With a Portrait, Plate VI.)

In the person of Professor Penfield the Mineralogical Society has lost an eminent Honorary Member, whose death has deprived Yale University of a brilliant and inspiring teacher, and has robbed our science of one of the most ardent of modern investigators. When a man imbued with the genius and the zeal for original research passes away in the fullness of years we can at any rate feel that he has accomplished the work for which he was best fitted and has bequeathed the full results of his abilities to his successors; but when a man, like Penfield, is taken in the prime of life, while his powers are ripe for the achievement of new discoveries, and while past success is being crowned by the promise of even more mature work, the loss is irreparable.

Penfield was born on January 16, 1856, at Catskill in New York, and was the son of a prominent merchant of that town; he was educated at home and at the local school, from which he passed to the academy at Wilbraham, Massachusetts, and thence, at the age of eighteen, to the Sheffield Scientific School at Yale University. He graduated with honours in 1877, having followed the course of chemistry. He had always been attracted towards mathematics and natural science, and shortly after taking his degree found an opening which led him into the paths of mineralogical research.

Professors G. J. Brush and E. S. Dana were just beginning their investigation of the minerals from Branchville, Connecticut, and they enlisted the services of Penfield and his classmate and life-long friend, H. L. Wells, who had become assistants in the laboratory of analytical chemistry, and were ready to undertake the necessary analyses. The two young men had thus at the outset of their career the opportunity of studying many new and interesting minerals. Penfield himself was shortly afterwards transferred as assistant to the mineralogical laboratory. Among the minerals which he analysed during this period were eosphorite, triploidite, dickinsonite, fairfieldite, fillowite, triphylite, childrenite, amblygonite, cymatolite, and spodumene.

In 1880 he proceeded to Germany, and for two semesters worked with Professor Fittig in Strassburg at organic chemistry, publishing a joint

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research with him on some organic compounds in 1882. Although Groth was at that time Professor of Mineralogy in Strassburg, and Penfield seems to have attended some of his lectures, his work was entirely on the organic side, and he was evidently contemplating the career of a chemist. His earlier work had, however, given him an interest and an experience in mineralogical chemistry, which were soon to find an application.

At this time the post of Instructor in Mineralogy at the Sheffield Scientific School, under Professor Brush, became vacant, and in 1881 Penfield was offered and accepted the position. During the next two years he published papers on monazite, scovillite, lithiophilite, descloizite, and beryl.

In 1884 he returned to Germany, in order to perfect himself in the methods of physical mineralogy, and studied during the summer semester with Professor Rosenbusch at Heidelberg. In 1888 he became Assistant Professor, and in 1893 full Professor of Mineralogy at the Sheffield Scientific School, and till the end of his life devoted himself with untiring zeal and energy to the twofold duties of his position—teaching and research.

Penfield's scientific publications extend over a period of very nearly thirty years, and amount to more than 110 in number. The earlier papers deal, for the most part, with the chemical composition of various minerals, but he became more and more interested in the study of their crystalline form, and towards the close of his life he devoted himself ardently to crystallographic problems and methods.

Throughout his whole career his researches were conducted with consummate skill and perseverance. Many of them led to results of the highest importance: it is only possible here to call attention to a few of the most prominent as types of his work.

One of the striking discoveries with which his name is associated is that of the isomorphous replacement of fluorine by hydroxyl. His very first published scientific paper was in 1877 on the composition of triphylite, one of the Branchville minerals. In the following year Brush and Dana, in the first of their papers upon these minerals, quoted Penfield's analysis of triploidite and pointed out that it led to the remarkable conclusion that hydroxyl can replace fluorine in a series of minerals so closely related as to be considered isomorphous. Little attention was paid to this statement at the time, except in the way of opposition: many of Penfield's subsequent analyses contributed further evidence of the same replacement, but they excited further opposition on

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the part of many chemists: Rammelsberg, for example, always refused to accept Penfield's conclusions, and as late as 1895 in the second supplement of his 'Mineralchemie' criticized the view as quite untenable. But by this time the evidence accumulated by Penfield was too strong to be ignored, and to-day hydroxyl plays a well-recognized part in mineral-formulae as equivalent to fluorine.

An important application of the principle is given in the memoir upon the chemical composition and related physical properties of topaz, which he made in conjunction with J. C. Minor, and which is a model of the best type of scientific research; work which introduces method and order where previously irregularities had prevailed in what was known of a common mineral. The authors showed that the percentage of water, which is only small, and had previously been regarded as the result of incipient decomposition, increases as that of fluorine diminishes, and that different specimens of topaz, if arranged in order of their fluorine-percentage, exhibit a regular progressive change in specific gravity, in refractive indices, in birefringence, and in optic axial angle. This enabled them to refer all topaz to the exceedingly simple formula $(AlF)_2SiO_4$, in which F is replaceable by OH.

Another most remarkable investigation, in which the same replacement is again invoked, was that of the chondrodite group, whose complex crystallographic characters had been deciphered by Scacchi, vom Rath, and others. Penfield and W. T. H. Howe succeeded in proving that the group consists of three species distinct in chemical composition as well as in crystalline form, and differing progressively by a molecule of Mg_2SiO_4; also that the length of the vertical axis is proportional to the number of the magnesium atoms in the formula. This striking morphotropic relationship rendered it possible to predict, for the first time in the history of mineralogy, the composition and form of a hitherto undiscovered mineral, and constituted a very notable scientific advance.

Among the more refined and difficult of his chemical researches may be mentioned those on tourmaline, canfieldite, spangolite, connellite, hamlinite, bixbyite, parisite, and his last published (1906) memoir on stibiotantalite.

In addition to the new minerals analysed for Brush and Dana, as mentioned above, he established, in conjunction with other authors, the following new species: bixbyite, canfieldite, clinohedrite, gerhardtite, glaucochroite, graftonite, hamlinite, hancockite, leucophoenicite, nasonite, nesquehonite, pearceite, roeblingite, and spangolite.

Possessed not only of extraordinary insight and quick apprehension,

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but also high inventive skill and dexterity of manipulation, Penfield could not fail to be one of the most gifted and successful of mineral chemists. He possessed the same qualities as a crystallographer, but his chief interest in crystallography was as a practical means of mineralogical research; and he devoted much time to the determination of the geometrical and physical characters, not only of minerals, but also of laboratory compounds. Among the most noteworthy of his crystallographic studies were the determination of clinohedrite, argyrodite, pearceite, sperrylite, and the double halides prepared by Wells.

In much of his work he enlisted the co-operation of his assistants and pupils.

Towards the end of his career, when his mind was much occupied with teaching, he devoted much thought to practical and graphic methods for the representation of crystals, and his protractors and the methods of drawing and projection which he described are now well known. To this period belong his papers upon the stereographic projection and its application to geographical maps and sailing charts, a subject for which he anticipated important developments in the future.

Penfield's clearness of exposition is nowhere better exhibited than in the revised and enlarged edition of G. J. Brush's 'Manual of Determinative Mineralogy, with an Introduction on Blowpipe Analysis,' which was published in 1896, and was followed by several other editions. The introductory chapters which he wrote for this book are models of clear and lucid treatment, and among the very best that can be placed in the hands of elementary students.

For a few years before his death his health was such that he was obliged to husband his strength with great care, and to set very definite limits to the work that he could undertake; nothing was more characteristic of the man than the courage and determination with which he set himself to do the work of which he was still capable. The planning and equipment of his new laboratories in Kirtland Hall was at that time a great pleasure to him.

In a cheery letter written a few months before his death he wrote—'I have to be careful not to take too much exercise or exert myself physically and my hours of work are very much shortened. I ought not to get tired in any way, and I tire easily, so I have to be very careful and constantly on my guard. I go to my laboratory every day and get in about five hours' work. As I look back upon the last three years I can see that something considerable has been accomplished. My

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troubles came just as my new laboratory was being started. It has taken a great amount of time and energy, but energy well spent, and the work is done. . . . It is a great delight now to work in my new building where the surroundings are most attractive and everything can be kept clean and neat.' Then after a description of the work on which he was engaged—'I have other things also on hand or in my mind, but I cannot put out work as fast as I formerly did. During hours allowed for study I prefer to work rather than read. I am not complaining; I am so much better than I ever expected to be three years ago.'

He died on August 12, 1906.

In January 1897 he had married Miss Grace Chapman of Albany, New York, who survives him.

None who knew Penfield could fail to be impressed by the earnestness, simplicity, and sincerity of his character: in scientific and intellectual matters he was inspired by a boyish enthusiasm and the keenest enjoyment of life and of the work and occupation of an active student and teacher. He endeared himself to colleagues and pupils alike, and made many warm and enduring friendships in Europe and America. Those who were privileged to enjoy his society when he visited Europe in 1894 and 1897, or to see him among his colleagues in their bachelor quarters at the Sheffield Scientific School, or later in the enjoyment of a happy married life in his own peaceful home, carried away the recollection of a sweet and affectionate nature, and feel that by his death they have lost one of the most warm-hearted and sincere of friends.

H. A. M.

Robert Philips Greg (1826–1906).

(With a Portrait, Plate VII.)

Born at Manchester on March 23, 1826, Robert Philips Greg passed away at his residence, Coles Park, near Buntingford, Hertfordshire, on August 20, 1906, in the 81st year of his age. His death has removed one who took a prominent part in the formation of the Mineralogical Society and who for the first ten years of its existence held the important office of Treasurer. He was compelled to relinquish this office in November 1885 by the continuance of the severe, and all but fatal illness which befell him in the summer of that year, and, as his health in the following year still remained precarious, he finally severed his connexion with the Society.

Among those who have assisted in the development of the mighty

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industry which centres at Manchester, the Greg family hold an honoured place. One of the best known of its members was Robert Hyde Greg (1795–1875). A man of exceptional capacity and gifted with more than ordinary business acumen, he had a prosperous commercial career, and the high position he held among the merchants of Manchester was recognized by his election in 1844 to the presidency of the Chamber of Commerce. Despite the engrossing claims of his widely-ramifying business, he took keen interest in public affairs and still found leisure for antiquarian and scientific pursuits. He played a leading part in the agitation in favour of Parliamentary Reform and the Repeal of the Corn Laws, and his fellow-citizens testified to the esteem in which they held him by electing him in 1839 as their representative in Parliament, without his previous knowledge and even against his will, at a time when he was enjoying a brief holiday in Switzerland. He had sufficient appreciation of minerals to expend in 1835 the sum of £1,300 on the purchase of the fine collection which had been formed by Thomas Allan (1777–1833), F.R.S., a well-known banker in Edinburgh; but his knowledge of mineralogy was slight and he made no additions to the collection. He married in 1824 Mary (1799–1878), the daughter of Robert Philips, a prominent Manchester merchant, and had by her a family of four sons and two daughters. Their eldest child was Robert Philips Greg.

At the time of young Greg's birth the old order of things was on the eve of change, but had not entirely vanished: in Manchester, merchants still lived on the spot where their working hours were spent, and his parents were occupying a house in King Street actually adjoining his father's business premises in Chancery Lane. Two years later they moved to Ardwick, then in the country, but now an ugly suburb dominated by factory chimneys and penetrated by railway viaducts, and eventually at the end of 1831 they settled down at Norcliffe Hall, close to the Quarry Bank Mill, which has belonged to the Greg family since 1783. Norcliffe Hall is pleasantly situated near Wilmslow in Cheshire, and about ten miles from Manchester. Here Greg spent most of his boyhood. He received his early education from the Rev. John Colston, of Styal, thenceforth a lifelong friend; in 1840 he was sent to Mr. Malleson's School, Hove, Brighton, where he remained two years; and after spending a single session at the Manchester New College he proceeded in 1843 to Edinburgh University. At the age of nineteen he commenced his business training, and on his coming of age in 1847 he was taken into partnership by his father. He seems never

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to have been completely absorbed in commercial affairs, and had certainly considerable leisure and opportunity for following up the many intellectual pursuits in which he was keenly interested. In 1857 he married Louisa Russell (1834–99), daughter of Samuel Stillman Gair, of Liverpool; they had no issue. They made their home first at Outwood Lodge, near Prestwich, and subsequently, in 1871, moved to Coles Park, which has been the property of the Greg family for upwards of 120 years. The house is charmingly placed amid sylvan surroundings, the natural beauties of which Greg did so much to enhance, and its approach recalls on a smaller and softened scale the features of a Derbyshire dale. Here they lived the remainder of their lives, and Greg engaged in the varied duties and occupations of a country gentleman. In 1873 he was appointed Justice of the Peace for the County, and in 1897 he succeeded to the Chairmanship of the Buntingford Bench. He enjoyed good health until his critical illness in 1885; he was affected by some form of blood-poisoning and had to suffer the amputation of his right foot, an operation which owing to the subsequent gangrening of the wound nearly cost him his life. Convalescence was tedious and slow, and two years elapsed before he recovered such measure of activity as an artificial substitute for his lost foot would allow. In 1895 his wife was attacked by the epidemic of influenza prevalent at that time, from which she never wholly recovered and to the after-effects of which she succumbed four years later. After her death Greg led a very quiet life; indeed, his own impaired health and the increasing weight of years would have in any case resulted in comparative seclusion. His death, though sudden, was not entirely unexpected. He was buried on August 23 at Westmill, of which village he was the squire, and the funeral was attended by a large number of relatives and others wishing to pay to him a last token of respect.

Until the time of his critical illness, Greg was an ardent collector; full of enthusiasm, he would spare no effort and grudge no expense to secure a coveted specimen. He began with spiders as a boy. On reaching manhood he turned his attention to the 'Allan' collection of minerals, then in his father's possession at Norcliffe Hall, and expended some £800 in the purchase of desirable specimens. Thanks to his energy, the collection became by far the finest private collection of minerals of the time in this country. The acquisition of specimens by purchase or exchange brought him into relations with collectors and others interested in minerals. In this way he made the acquaintance of W. G. Lettsom (d. 1887), like himself a keen collector, with whom he

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collaborated in the production of the 'Manual of the Mineralogy of Great Britain and Ireland', which though published in 1858—nearly half a century ago—still remains the only work dealing with the general distribution of minerals in the British Isles. The book was written in four years, a remarkably short space of time for a work of that kind. With its publication Greg's interest in minerals seems to have waned, and in 1860, two years after its publication, he negotiated on behalf of his father the sale of the collection to the Trustees of the British Museum. He published a few papers on mineralogical subjects, the most important of which are the description of a new oxychloride of lead, matlockite, the discussions of the crystalline forms of leucophane and of rhodonite, and a paper with the late Professor Heddle on British pectolites. During the succeeding eighteen years he devoted much attention to the study of meteorites and meteor-showers, mainly from the astronomical point of view. He was a member of the Committee appointed by the British Association to report on observations of luminous meteors, and he wrote a large number of papers bearing on this subject, which form an enduring contribution to science. He got together a small collection of meteorites which was sold in 1865 to the Trustees of the Calcutta Museum for £500, and commenced in 1875 the formation of a collection of prehistoric implements which he sold in 1889 for £304. In consequence doubtless of the lengthy visit which he and his wife together with a party of relations paid to Egypt and the East in 1880, he commenced, three years later, a book on the comparative philology of the old and new worlds; it, however, did not actually appear till 1893, owing to the intervention of the severe illness already alluded to.

Besides being a member of the Mineralogical Society (1876–86), Greg belonged to the Royal Astronomical Society (1868–81), the Society of Antiquaries (1878–94), and the Geological Society (1853 till his death), and he frequently attended the meetings of the British Association. According to the Royal Society's Catalogue of Scientific Papers, Greg published twenty-six papers, and was joint author of two others, in addition to the two books mentioned above.

G. F. H. S.

John George Goodchild (1844–1906).

Mr. J. G. Goodchild, who died at Edinburgh on February 21, 1906, was an officer of the Geological Survey, to which he became attached in 1867. He was born near London on May 26, 1844. For many years

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he was engaged in mapping part of the Lake District, and, although glacial geology occupied much of his attention while there, he became greatly interested in the local minerals and published 'Contributions towards a List of the Minerals occurring in Cumberland and Westmorland.' This paper appeared in the 'Transactions of the Cumberland and Westmorland Association' (1882–5), of which he was editor. Compelled by ill-health to abandon field-work, he was stationed for some years in the London office of the Survey, whence he was transferred to Edinburgh in 1887. There he took charge, first of the collections of the Scottish Survey, and afterwards of the mineral collection of the Royal Scottish Museum, formerly the 'Edinburgh Museum of Science and Art'. Under the influence of Dr. M. F. Heddle, whose collection passed officially into his charge, he became an enthusiastic student of the minerals of Scotland, and many papers, dealing especially with their probable genesis, proceeded from his active pen. He prepared, too, an excellent guide to the collections under his care, and on Heddle's death he undertook the editing of 'The Mineralogy of Scotland'. The manuscript required much labour in its preparation for press, and important additions, including many plates, were made by the editor. Mr. Goodchild was a man of extremely varied interests, giving at times serious attention to ornithology, botany, ethnology, and archaeology. He was a ready writer (being the author of some two hundred papers) and remarkably fluent as a speaker, so that he was induced to devote much time to lecturing, and in spite of long continued ill-health achieved in this direction pronounced success.

Vivant Léon Moissenet (1831–1906).

By the death of Professor Moissenet at Chaumont on February 2, 1906, the Society loses one of its earliest Honorary Members, he having been elected in 1877. He was born on August 2, 1831, at Chalon-sur-Saône. After passing through the courses of the Polytechnic School and the School of Mines in Paris, he became attached to the French Department of Mines, from which he retired in 1893 with the title of Honorary Inspector General of Mines. In 1869 he became Professor of Assaying and Analytical Chemistry in the School of Mines at Paris. In earlier years he paid several visits to the mining districts of England, and his first paper, in 1857, was on the deposits of lead-ore in the Carboniferous Limestone of Flintshire. In 1874 he published a pamphlet entitled 'Études sur les filons du Cornwall', which was translated into English by Mr. J. H. Collins in 1877.

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Pierre Curie (1859–1906).

Professor Curie, the co-discoverer with his wife, Madame Sklodowska Curie, of the element radium, and also well known as a physicist, met his death as the result of a street accident in Paris on April 19. He was born in Paris on March 15, 1859, and received his early training at the Sorbonne, graduating as Doctor of Science in 1895. In the same year he became Professor of Physics in the Municipal School of Physics and Chemistry, and in 1900 Professor at the Sorbonne. Some of his earlier work, done in conjunction with his elder brother Jacques Curie, related to the piezoelectricity of crystals (1880); he also published papers on the symmetery of crystals (1884–5) and the capillarity constants of their faces (1885). Electrical researches occupied his attention until his work on radio-activity led to the discovery, in 1898, of radium in the mineral pitchblende. He was a life-member of the French Mineralogical Society.

Henry Augustus Ward (1834–1906).

Dr. Henry A. Ward, who, at the age of seventy-two, was knocked down and killed by a motor-car at Buffalo on July 4 last, was born at Rochester, New York, on March 9, 1834. After studying for four years at the School of Mines in Paris, he became, in 1859, Professor of Natural Science in the University of Rochester, a post which he held till 1865. For a time he acted as superintendent of gold mines in Montana and South Carolina, but soon afterwards returned to Rochester and founded the now well-known 'Ward's Natural Science Establishment', with which he was actively connected for over thirty years. Always an enthusiastic and energetic collector and distributor of specimens belonging to various branches of natural history, he in later years turned his attention largely to meteorites. He could tell many interesting tales of adventure which had befallen him during his travels in out-of-the-way places all the world over, undertaken with the object of securing examples of meteoric falls not represented in his collection. After disposing of large collections of meteorites to the Field Columbian Museum in Chicago and to Mr. C. S. Bement of Philadelphia, he commenced in 1894, at the age of sixty, the Ward-Coonley collection, which in the comparatively short space of ten years became one of the finest in existence. A detailed catalogue of this collection, together with a list of all known meteorites, was published by Professor Ward in 1904 ('Catalogue of the Ward-Coonley collection of Meteorites', Chicago, 1904, 4to, pp. xii +

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113, with 10 pls.). At that time the collection, which is now exhibited in the American Museum of Natural History at New York, contained representatives of 603 meteoric falls, with a total weight of material of 2,495 kilograms. Professor Ward was the author of several papers on meteorites, and had collected a large amount of information relating to these bodies, on which he intended to publish a treatise.

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REVIEW.

The Gem-cutter's Craft. By LEOPOLD CLAREMONT. Pp. xvi. + 296, small quarto; with 118 illustrations. (London: George Bell & Sons, 1906. Price 15*s.* net.)

The title of this book, together with the statement in the preface that it is perhaps the first work on precious stones that has been written by a practical gem-cutter, would lead us to expect full details and valuable hints concerning the work of the lapidary. In this, however, we are considerably disappointed, for the description of the modern ethods of cutting precious stones occupies less than thirty pages, and of this a very large portion is taken up with illustrations, which though effective exhibit considerable sameness. What we do find are descriptions to the different kinds of precious stones, but these descriptions leave much to be desired.

Throughout the book there are numerous errors, errors not only in the mis-statement and hopeless confusion of principles, facts, and quantities, but also in spelling and grammar. To select only two examples: diamond is said to crystallize as a 'six-sided octahedron', and corundum as scalenohedra. Blunders of such a kind as these one expects to meet with only in the hurried answers to an examination paper; but when the author has presumably had the opportunity of referring to the books which he recommends to his readers, they are inexcusable. In this bibliography, by the way, we miss a mention of Professor Church's well-known Handbook.

The book is well illustrated, though the figures are scarcely referred to in the text. Some of the photographic reproductions of uncut specimens of gem-stones come out very successfully, whilst others would have been better omitted. The specimens represented are in the British Museum collection of minerals, and were photographed by Mr. T. C. Hepworth, whose notes could not have been referred to, since the statements of the relative sizes of the specimens and figures are invariably incorrect. The book is well printed and issued in an attractive form, and this is the most that can be said in its favour.

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ABSTRACTS.

Die Skiodromen. Ein Hilfsmittel bei der Ableitung der Interferenzbilder. (F. Becke, Min. Petr. Mitt. (Tschermak), 1905, vol. xxiv, pp. 1–34).[1]

Professor Becke has made a careful study of the conditions that determine the form and position of the shadows—bars or brushes—seen when sections of anisotropic crystals are examined in convergent light between crossed nicols, and shows how, by an examination of these phenomena, both the optical characters of the crystal and the position of the section can be approximately determined.

The principal optical directions are first considered as projected from the centre on to the surface of a sphere. About the points of emergence of the optic axes as foci two systems of confocal spherical ellipses[2] are drawn. One system has the acute bisectrix as centre, the other the obtuse bisectrix. The two systems cut each other at right angles and form a network covering the sphere. At any point of intersection the tangents to the curves are the directions of vibration of the two wave-fronts whose normals meet the sphere at that point.

The curves which have the acute bisectrix as centre are termed equatorial ellipses, and those with the obtuse bisectrix as centre, meridian ellipses. In uniaxial crystals the former are represented by circles having the points of emergence of the optic axis as centre, and the latter by the great circles passing through those points.

The ellipses of one system have the tangential vibrations faster than the normal vibrations and are referred to as α-ellipses. Those of the other system whose tangential vibrations are the slower are termed in same manner γ-ellipses. In positive crystals the α-ellipses are equatorial and the γ-ellipses meridian, while in negative crystals the reverse is the case.

In order to apply these principles to the investigation of the images afforded by sections of minerals in convergent polarized light, the sphere is projected orthogonally on to a plane which is parallel to the plane of the section, and therefore at right angles to the axis of the microscope.

[1] Compare this volume, p. 230.

[2] A spherical ellipse is a curve on the surface of a sphere which has the property that the sum of the angular distances of any point upon it from two foci on the sphere is constant.

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The distance of each point on the plane of projection from the foot of the perpendicular through the centre of the sphere is proportional to the sine of the angular distance on the sphere, a relation that approximately holds good in the image seen in convergent light.

The projections of the ellipses are called skiodroms ('shadow-tracks'), and they may be distinguished as equatorial and meridian, or α- and γ-skiodroms, according to the characters of the ellipses from which they are projected. In the centre of the field of view they cut each other at right angles, but elsewhere they are oblique, and the obliquity increases with the distance from the centre. See figs. 1 and 2.

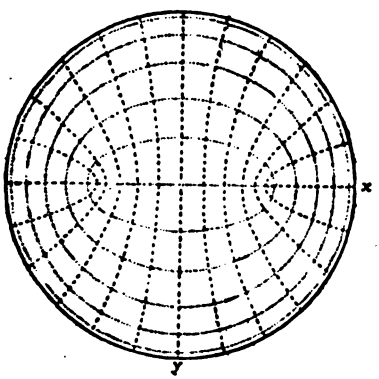

Fig. 1.

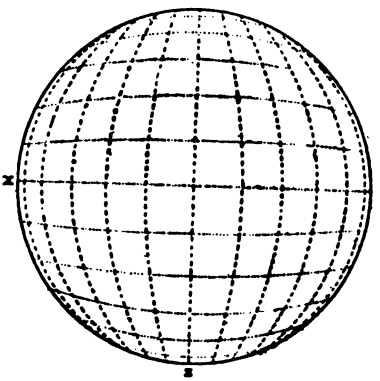

Fig. 2.

Fig. 1.—Skiodroms of a biaxial, negative crystal ($2V=60°$) projected on a plane at right angles to the acute bisectrix. The dotted lines are the equatorial skiodroms: the crystal being negative, these are γ-skiodroms, that is, their tangents are parallel to the vibrations of the wave-fronts with less velocity. The interrupted lines are the meridian skiodroms, which are here α-skiodroms.

Fig. 2.—The same projected on a plane parallel to the optic axial plane.

These figures first appeared in Denkschr. Akad. Wiss. Wien, 1904, vol. lxxv.

In any position of the section relatively to the nicols the vibrations that are parallel to those of either nicol are extinguished, and the curve of one or more branches uniting all the points where this is the case is called an isogyre. Near the centre of the field, where the skiodroms meet at right angles, the vibrations parallel to both systems of skiodroms are extinguished at the same points at the same time and the isogyre is represented by a distinct dark bar or curve; but near the periphery, where the skiodroms, and therefore the traces of the vibrations, are distinctly oblique to one another, the two vibrations at any point do not

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extinguish simultaneously and the isogyre is represented by a diffused brush.

Professor Becke describes in detail the forms of the skiodroms and the resulting shadows or isogyres. Petrologists are already more or less familiar with the shape and movements of the latter when an axis of optical symmetry (a bisectrix or optic normal) or an optic axis is in the field of view, and there is little difficulty in recognizing the position of the section and the optical characters of the crystal. It will therefore only be necessary in this place to deal with sections which do not come under this heading, though the same principles are, of course, applicable to all sections, subject only to such obvious modifications as the special conditions of each case imply.

When the isogyre passes through the centre of the field it is termed a central isogyre. The vibrations in the centre of the field are then parallel to those of the nicols and the section is in the position of extinction in parallel polarized light.

When the normal to the section lies in a plane of optical symmetry, the central isogyre is straight and parallel to the direction of vibration of one of the nicols.

The normals to all oblique sections of uniaxial crystals lie in a plane of optical symmetry, and have therefore a straight central isogyre parallel to a nicol. On rotating the section, the isogyre moves laterally and, while remaining approximately parallel to its central position, shows a slight pendulous motion. The end of the isogyre nearer the optic axis moves round the circumference of the field in the same direction as the stage rotates and is termed by Professor Becke the homodrom end; the other extremity of the isogyre, which moves round the circumference in the opposite direction, he calls the antidrom end.

If the normal to a section of a biaxial crystal lie in the optic axial plane, the phenomena are similar to those of an oblique section of a uniaxial crystal, except that the pendulum motion of the isogyre is more pronounced and that the antidrom end moves faster than the homodrom end which is that nearer an optic axis. See fig. 2, p. 232 of this volume. If, on the other hand, the section-normal lie in a plane of optical symmetry passing through the optic normal, the homodrom end, which is directed to the bisectrix in the same plane of symmetry, moves faster than the antidrom end, and the movement of the whole isogyre resembles that of a fan. See fig. 5, on the same page.

If the normal to a section does not lie in a plane of symmetry, the central isogyre is usually curved, but its movements are similar to those

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already described, varying in character according as the normal approximates to the optic axial plane or one of the other planes of symmetry.

In the case of most sections a distinction can be made between longitudinal skiodroms (Längs-Skiodromen) and transverse skiodroms (Quer-Skiodromen), the former showing less curvature than the latter within the limits of the field. The central isogyre either coincides with the central longitudinal skiodrom or makes with it an angle of less than 45°. In uniaxial crystals the longitudinal skiodroms are always meridian, while in biaxial crystals which are not neutral—that is, in which the optic axial angle is not exactly a right angle—they are meridian in the majority of cases, being equatorial in limited areas between the acute bisectrix and the optic axes and between the obtuse bisectrix and the optic normal. These areas diminish in size as the optic axial angle decreases.

The direction of vibration of the nicol, which either coincides with or more nearly approximates in direction to the central isogyre in the centre of the field, is parallel to the longitudinal skiodrom at that point. When this is the direction of the slower vibration, i. e. when the longitudinal skiodroms represent γ-ellipses, the section is said to have a positive reaction; when it is in the direction of the faster vibration the section has a negative reaction.

In uniaxial crystals the sign of the crystal is always that of the section; while in biaxial crystals this relation holds good more often than not, and its probability increases as the optic axial angle diminishes.

Professor Becke gives the following rule for determining the sign of the reaction of a section:—

Rotate the stage till the central isogyre is either parallel to the north and south cross-wire, or makes an angle of less than 45° with it, and has its homodrom end towards the north. Then insert a gypsum-plate with the direction of the α (fast) vibration north-west and south-east. If the colour fall to the east and rise to the west of the isogyre, the longitudinal skiodroms correspond to the γ-ellipses and the reaction of the section is positive [1]. If the colours rise to the east and fall to the west, the reaction will be negative.

[1] This result is due to the fact that the longitudinal skiodroms—which in a positive section are the directions of vibration of the slow waves—converge towards the north. In the centre of the field they are at 45° with the directions of vibration in the gypsum-plate and do not influence the colour; on the east they approximate in direction to the vibrations of the fast waves in the gypsum and compensation occurs; while on the west they approximate to the vibrations of the slow waves in the gypsum, and the relative retardation in the gypsum is increased.

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A straight central isogyre which makes an angle of 45° with the vibrations of the nicols indicates a section whose normal lies in the plane including an optic axis and the optic normal of a crystal whose optic axial angle is a right angle. J. W. E.

Messung des Winkels der optischen Achsen aus der Hyperbelkrümmung. (F. Becke, Min. Petr. Mitt. (Tschermak), 1905, vol. xxiv, pp. 35–44.)

In this communication Professor Becke describes a graphic method of determining the optic axial angle of a crystal from the shape of the hyperbolic brushes or isogyres, when a section, examined in convergent polarized light, shows an optic axis in the field. The isogyre is traced in different positions by means of a camera-lucida and a rotating table connected mechanically with the rotating stage and turning with it. The latter mechanism is unnecessary with a microscope, the nicols of which rotate, and in the following brief description of the principle of the method it is assumed that such a microscope is employed.

The nicols are first rotated till the isogyre shows a straight line, the trace of the optic axial plane, through the optic axis parallel to the direction of vibration of one of the nicols. This is traced by means of the camera-lucida. The nicols are then rotated through 45°, and the hyperbolic curve now seen is traced on the same diagram. The point of intersection A_1 of the two tracings corresponds to the optic axis. The tracing of the optic axial plane and that of the optic axis A_1 and a point H on the hyperbola are then transferred to a stereographic projection. Each point to be transferred is determined in terms of its angular position (azimuth) and distance from the centre of the field in convergent polarized light. The former remains the same in the stereographic projection, and from the latter the angular distance and hence the distance in the stereographic projection can be easily obtained.

In the stereographic projection a great circle is drawn through the optic axis A_1 and the point H on the hyperbola. Through H a straight line HF is drawn parallel to the second position of one of the nicols and in the direction of the acute bisectrix. A great circle is then drawn through H making the angle A_2HF equal to the angle A_1HF, and the point A_2, where it meets the great circle representing the optic axial plane, will be the projection of the second optic axis. The length of the arc A_1A_2, which is equal to the acute optic axial angle, is then determined in the usual manner.

Professor Becke gives full details of the procedure to be followed. The results obtained are under favourable conditions correct within two degrees. J. W. E.

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Ueber die dunklen Büschel von Dünnschliffen im convergenten Lichte. (H. Hilton, Zeits. Kryst. Min., 1906, vol. xlii, pp. 277–278.)

Mr. Hilton shows that in the study of the bars and brushes (isogyres) seen in convergent light and the determination of the optic axial angle of crystals by this means (see preceding abstract), the gnomonic projection may be employed for the representation of points which are not too far removed from the centre of the field. He states that if ρ be the radius of the sphere, and if in the gnomonic projection the axes of X and Y be parallel to the directions of vibration of the nicols, and x_1y_1 and x_2y_2 be the projections of the optic axes, then the equations of the partial isogyres, which are the loci of the points where the tangents of the projections of the spherical ellipses are parallel to the axes of X and Y respectively, will be the following :—

$$x\{(y^2-\rho^2)(y_1+y_2)+2y(\rho^2-y_1y_2)\}=(y^2+\rho^2)\{y(x_1+x_2)-(x_1y_2+x_2y_1)\}$$

and

$$y\{(x^2-\rho^2)(x_1+x_2)+2x(\rho^2-x_1x_2)\}=(x^2+\rho^2)\{x(y_1+y_2)-(x_1y_2+x_2y_1)\}.$$

J. W. E.

The Isomorphism and Thermal Properties of the Feldspars. A. L. Day and E. T. Allen. Preliminary notice: Amer. Journ. Sci., 1905, ser. 4, vol. xix, pp. 93–142. Full account, with introduction by G. F. Becker, and optical study by J. P. Iddings: Carnegie Institution, Washington, publication No. 31, 1905, 95 pp., 26 plates; translation in Zeits. physik. Chem., 1905, vol. lix, pp. 1–54, 7 plates. (Abstract in Nature, 1905, vol. lxxii, p. 258).

On Wollastonite and Pseudo-Wollastonite,—Polymorphic forms of Calcium Metasilicate. E. T. Allen and W. P. White, with optical study by F. E. Wright. Amer. Journ. Sci., 1906, ser. 4, vol. xxi, pp. 89–108.

The Lime-Silica Series of Minerals. A. L. Day and E. S. Shepherd, with optical study by F. E. Wright. Ibid., 1906, vol. xxii, pp. 265–302; and Journ. Amer. Chem. Soc., 1906, xxviii, pp. 1089–1114.

Minerals of the Composition $MgSiO_3$; a Case of Tetramorphism. E. T. Allen, F. E. Wright, and J. K. Clement. Ibid., 1906, vol. xxii, pp. 385–438.

The papers, of which the titles are quoted above, give the results so far published of a remarkable series of researches now being carried out in the Geophysical Laboratory of the recently founded Carnegie Insti-

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tution of Washington. They have for their aim the preparation of the various rock-forming minerals in a pure and crystallized condition, and the determination, as far as possible, of all their physical properties (thermal, optical, specific gravity, &c.), their conditions of formation and alteration, and the relations of the different polymorphic forms to each other. The large number of experiments are performed in an electric furnace which can be regulated with delicacy up to temperatures of 1,600°C.; the observations are plotted on curves and discussed from a physico-chemical standpoint. Many important results have already been obtained and some interesting deductions bearing on petrology have been drawn.

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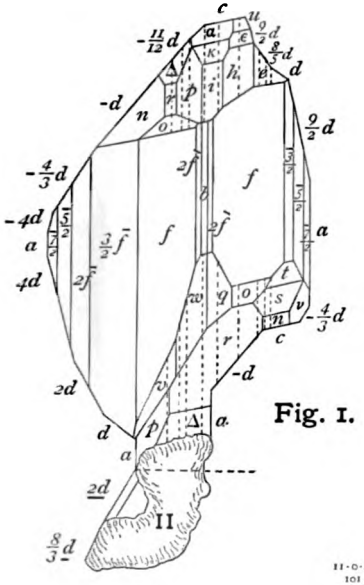


Fig. 1.

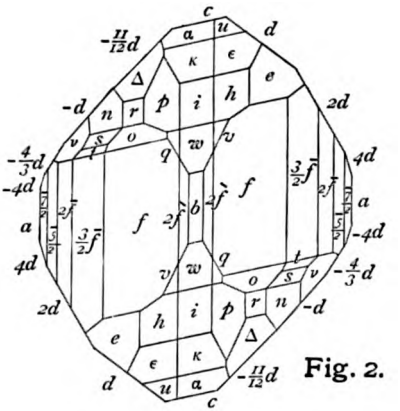


Fig. 2.

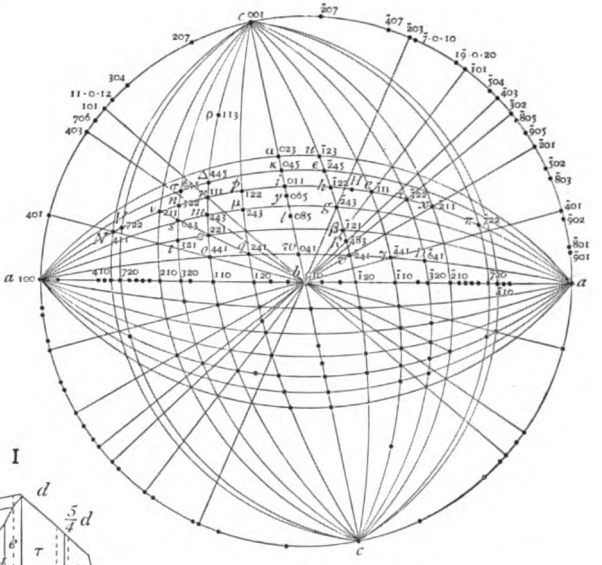


Fig. 5.

Fig. 4.

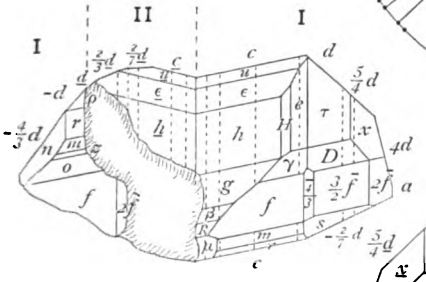
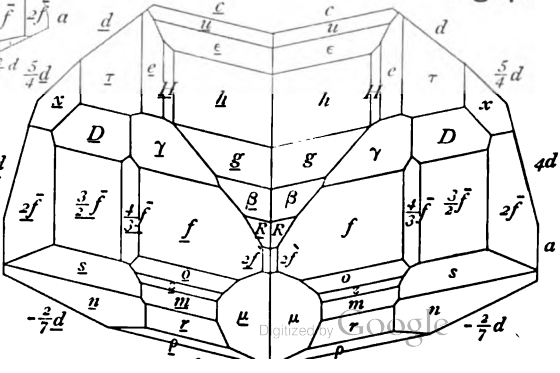


Fig. 3.



C.O.T. del.

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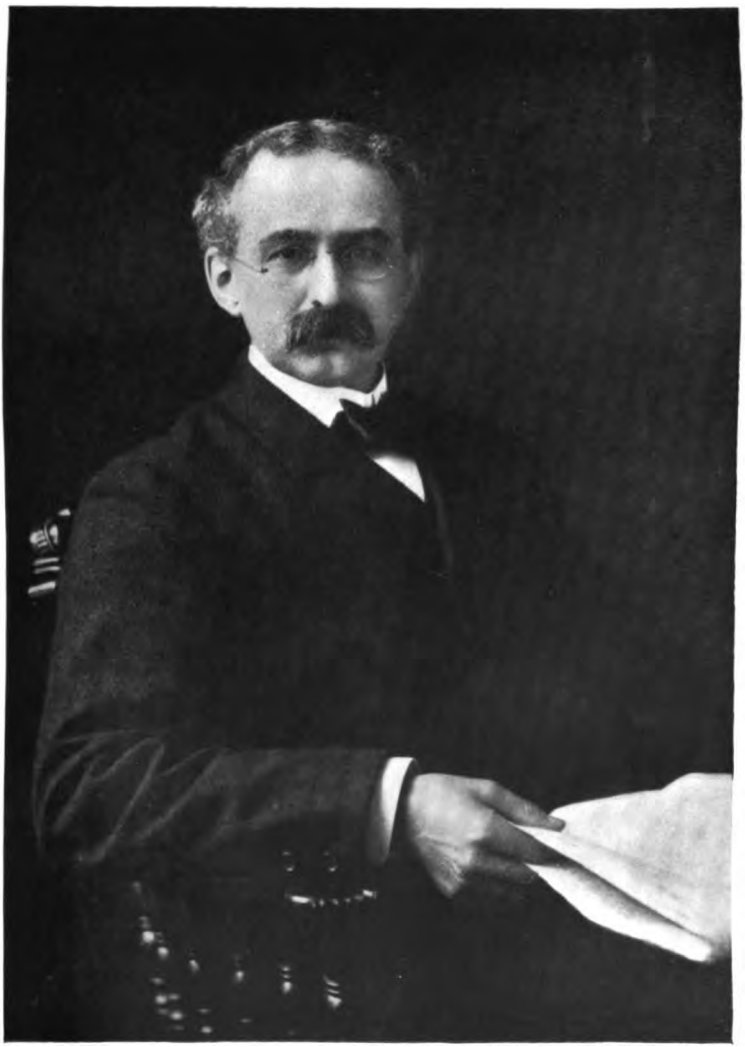

SAMUEL LEWIS PENFIELD.

(At the age of 46.)

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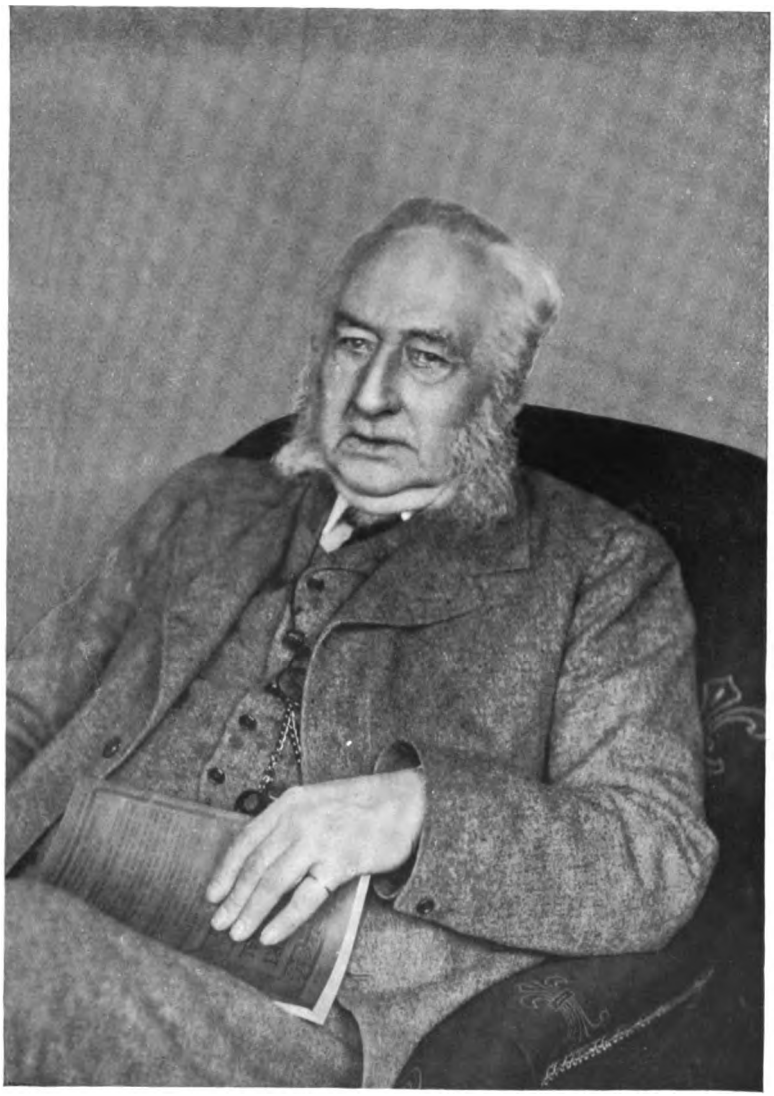

ROBERT PHILIPS GREG.
(At the age of 79.)

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THE MINERALOGICAL MAGAZINE

AND

JOURNAL OF

THE MINERALOGICAL SOCIETY.

No. 67. September, 1907. Vol. XIV.

Red silver minerals from the Binnenthal, Switzerland.

On their Crystallographical Characters.

By G. F. Herbert Smith, M.A., D.Sc., F.G.S.

And on their Chemical Composition.

By G. T. Prior, M.A., D.Sc., F.G.S.

Assistants in the Mineral Department of the British Museum.

[Read March 15, and June 14, 1905.]

FOR many years past Mr. R. H. Solly has been accustomed to spend each succeeding summer in the quest of mineral specimens in the neighbourhood of the village of Binn, Switzerland, particularly of those occurring in the white crystalline dolomite of the Lengenbach quarry, and his patient energy has been rewarded by the discovery, not only of material which has thrown fresh light on previously known minerals, but also of specimens which on examination proved to represent species new to science. Especially important was the discovery in 1903 of small, and often minute, blood-red crystals which differed both in colour and in streak from realgar, a common mineral in the quarry. From goniometrical measurement of a few crystals suitable to the purpose, Mr. Solly concluded that they belonged to two distinct species, both of which were new, and he accordingly assigned[1] to them the names hutchinsonite, after Dr. Arthur Hutchinson, Demonstrator of Mineralogy in the Uni-

[1] Min. Mag., 1905, vol. xiv, pp. 72, 74.

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versity of Cambridge, and smithite, after one of the authors of this paper. Upon hearing of this discovery, Dr. C. O. Trechmann courteously sent to Mr. Solly a specimen, purchased by the former in 1902, on which he had noticed a few small red crystals. These proved on examination to differ in morphological characters from the crystals of both the previous species, and belonged, therefore, to a third new species, for which Mr. Solly proposed[1] the name trechmannite after the owner of the specimen.

In the following summer (1904) Mr. Solly carefully scrutinized every specimen that came into his hands, and was successful in finding more hutchinsonite and smithite, and also a single, well-developed crystal of trechmannite[2] springing from a crystal of tennantite ('binnite'). The search in 1905 was comparatively barren as regards the first two species, but yielded a fine crystal of trechmannite[3], which again was situated on tennantite; and again, during the summer of last year, some fine crystals of trechmannite have come to light, but scarcely any hutchinsonite and smithite were encountered.

The best of the specimens collected by Mr. Solly, together with the actual crystals measured by him, have been acquired by the Trustees of the British Museum, and in accordance with his wishes the investigation of the red minerals has been continued by the authors. In the case of the first two of the species described in the present paper, the investigation may be considered fairly complete; but it has still not been found possible to collect a sufficient amount of the third, and the rarest of these red minerals, trechmannite, for a satisfactory determination of the chemical composition.

I. Hutchinsonite.

This mineral has especial interest because it contains a considerable amount, nearly 20 per cent., of the rare element thallium[4], which had previously been known as an essential constituent in only two minerals, crookesite, in which it was first found, and lorandite. Although it occurs in smaller crystals than is the case with either of its companion species it is, at any rate so far as can be judged from the specimens which have hitherto been found, comparatively speaking, quite as common and plentiful as smithite; nevertheless, owing to its intimate

[1] Loc. cit., p. 75.
[2] Loc. cit., p. 75.
[3] Min. Mag., 1906, vol. xiv, p. 189.
[4] The discovery was announced by Dr. Prior in a letter to 'Nature', April 6, 1905, vol. lxxi, p. 534.

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association with sartorite, or other sulpharsenite of lead, the selection of pure material for a trustworthy determination of the chemical composition proved a matter of extreme difficulty, and, as will be seen below, the whole amount of material collected for the purpose was very small.

1. *Morphological Characters.*

The crystals are of two different types. In the first case the mineral is found in radiating tufts of tiny needles, less than 0·1 mm. in section and less than 1 mm. in length, situated in little cavities in the dolomite. A peculiar feature of these needles added still further to the difficulty of collecting material for analysis. Both the colour and the streak varied considerably: some of the needles were a rich red in hue and gave a vermilion streak; while others, on the contrary, were much deeper in colour with a decidedly brownish tinge, and gave a deep cherry-red streak. On the other hand, the angles measured in the prism-zone, in which alone on these minute crystals were trustworthy observations obtainable, were identical within the limits of error, and both kinds display the characteristic form *g* (140). Such similarity in form and such divergence in colour seemed difficult to reconcile, and accordingly in the selection of material for analysis care was taken to keep the two kinds apart. In the second case the mineral occurs in thicker crystals, usually about 0·4 mm. in length and 0·2 mm. in section, coating crystals of sartorite and rathite. When situated on the prism-faces, the crystals of hutchinsonite are arranged in parallel position, so that their prism-edge is parallel to that of the sartorite or rathite. Somewhat shorter crystals have been deposited without any definite orientation on the terminal faces of the same crystals; and similar, but far smaller, crystals are found irregularly placed on crystals of smithite. When deposited on a crystal of a sulpharsenite of lead, the hutchinsonite forms a skin so thin that it is impossible to separate the two minerals, and in consequence a crystal of hutchinsonite removed for measurement may appear nearly black in colour and almost opaque. It may be remarked that frequently the black minerals without definite crystalline form, which are embedded in the dolomite, merge into some red mineral—probably hutchinsonite—as may be detected by scratching the surface.

In addition to the minerals on which it is actually deposited, sartorite, rathite, and smithite, the minerals associated with hutchinsonite are blende, iron-pyrites, realgar, and orpiment.

The habit of the crystals is invariably prismatic, and the dome- and

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pyramid-faces are rarely developed so largely as those in the prism-zone. Indeed, in the case of the minute needles the terminal faces are so infinitesimal in size that no determination of their positions was possible. The illustrations (figs. 1–4) represent actual crystals, all of which were intimately associated with sartorite and rathite. That depicted in fig. 2 was removed from a prism-face of sartorite. The crystal shown in fig. 4 is remarkable for the large number of dome- and pyramid-faces present.

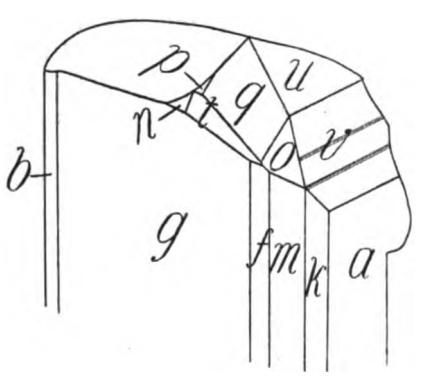

Fig. 1.

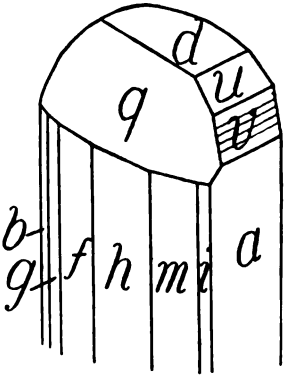

Fig. 2.

Crystals of Hutchinsonite.

The crystal illustrated in fig. 1 calls for particular note, because it alone of all the crystals examined provided any opportunity for the determination of the optical characters. Fig. 3 shows a curiously shaped crystal.

Hutchinsonite crystals are almost invariably characterized by the predominance of the form $g\{140\}$ in the prism-zone. It will be remarked how very close are certain angles in the prism- and dome-zones, e. g.:—(100):(320)=47° 27′ and (100):(201)=47° 16′; (100):(840)=65° 21′ and (100):(101)=65° 12½′. There is, however, no marked approximation to tetragonal symmetry. The parametral plane adopted is different from Mr. Solly's, his (111) corresponding to (211), and in general his (hkl) to $(2h.k.l)$. This slight modification effects some simplification in the indices of the forms as a whole.

All the crystals were measured on the three-circle goniometer from the face $a(100)$, which was on all of them well developed, as origin, and the measurements made on the fourteen best crystals are summarized in table I. They were all small [illegible] and the largest did not exceed

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TABLE I (Hutchinsonite).

Measurements from $a = (100)$.

Orthorhombic; $a : b : c = 1{\cdot}6343 : 1 : 0{\cdot}7549$.

Form.	Indices.	Calculated Values.		Observed Means.		Number.	Limits of Observations.	
		Azimuth.	Distance.	Azimuth.	Distance.		Azimuth.	Distance.
c	001	*	*	90° 0′	90° 0′	3	... 90° 15′	... 90° 29′
U	102	,,	77° 0′	,, ,,	77 3	3	... ...	76° 59′ – 77 9
V	304	,,	70 53½	,, ,,	70 40	1		
d	101	,,	65 12½	,, ,,	65 12	12	... ...	64 42 – 65 30
W	302	,,	55 17	,, ,,	55 24	1		
u	201	,,	*	,, ,,	47 16	12	... ...	47 10 – 47 22
X	703	,,	42 51	,, ,,	42 35	1		
v	301	,,	35 49	,, ,,	35 42	11	... ...	35 0 – 36 16
w	401	,,	28 25½	,, ,,	28 35	3	... ...	28 33 – 28 39
Y	501	,,	23 25	,, ,,	23 34	1		
Z	601	,,	19 50½	,, ,,	20 0	1		
θ	825	78° 12′	54 43½	72 51	54 17	1		
e	012	69 19	90 0	69 21	90 1	1	69° 19′ – 69 28	
x	524	,, ,,	61 37	,, ,,	61 40	2	,, ,, ,, ,,	... 61 40
C	312	,, ,,	57 2½	,, ,,	57 20	1	,, ,, ,, ,,	
O	144	*	84 44	52 57	84 45	1	52 39 – 53 6	
r	122	,,	79 33	,, ,,	79 34	8	,, ,, ,, ,,	79 0 – 79 51
p	111	,,	69 46	,, ,,	69 36	10	,, ,, ,, ,,	69 15 – 69 56
q	322	,,	61 3½	,, ,,	61 6	11	,, ,, ,, ,,	60 42 – 61 25
o	211	,,	53 36	,, ,,	53 38	10	,, ,, ,, ,,	53 21 – 54 0
P	522	,,	47 20	,, ,,	47 16	1	,, ,, ,, ,,	
Q	311	,,	42 7	,, ,,	42 15	1	,, ,, ,, ,,	
R	411	,,	34 8½	,, ,,	34 10	1	,, ,, ,, ,,	
A	332	41 27	65 22	41 12	65 25	1		
s	142	33 31	82 44	33 25	82 15	4	33 0 – 33 40	81 40 – 82 44
n	121	,, ,,	75 41½	,, ,,	75 38	5	,, ,, ,, ,,	75 15 – 75 56
t	342	,, ,,	69 4	,, ,,	68 50	3	,, ,, ,, ,,	68 32 – 69 1
N	221	,, ,,	62 58	,, ,,	62 52	2	,, ,, ,, ,,	62 49, 62 55
T	742	,, ,,	48 14½	,, ,,	48 14	1	,, ,, ,, ,,	
b	010	*	*	0 0	90 0	11	... ...	... 90 27
g	140	,,	81 18	,, ,,	81 24	20	... ...	81 7 – 81 57
K	250	,,	76 15	,, ,,	76 24	1		
f	120	,,	72 59½	,, ,,	73 2	9	... ...	72 52 – 73 6
h	340	,,	65 21	,, ,,	65 22	17	... ...	64 16 – 65 46
m	110	,,	58 32	,, ,,	58 33	13	... ...	58 0 – 59 16
i	540	,,	52 35½	,, ,,	52 30	11	... ...	52 11 – 53 3
k	320	,,	47 27	,, ,,	47 14	10	... ...	46 52 – 47 32
l	740	,,	43 2½	,, ,,	42 50	7	... ...	42 18 – 43 7
F	210	,,	39 23	,, ,,	39 0½	2	... ...	39 0, 39 1
G	730	,,	35 0½	,, ,,	34 59	1		
H	830	,,	31 30	,, ,,	30 59	1		
a	100	,,	*	,, ,,	0 0	19		

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1 mm. in the longest direction. Of the forty-two forms observed, twenty-four, viz. *a*, *b*, *c*, *G*, *F*, *l*, *k*, *i*, *m*, *h*, *f*, *g*, *Y*, *w*, *v*, *u*, *W*, *d*, *U*, *Q*, *o*, *q*, *p* and *r*, were given by Mr. Solly. The two forms (011) and (850), equivalent to (011) and (16·5·0) according to the parameters adopted in this paper, which were observed by him, have not been noticed on any of the crystals. The means of the observed values agree very closely with Mr. Solly's determinations.

In the prism-zone the forms $a\{100\}$, $k\{320\}$, $m\{110\}$, $h\{340\}$, $f\{120\}$, and particularly $g\{140\}$, are well developed; $b\{010\}$ is common, but small.

In the dome-zone the more prominent forms are $v\{301\}$, $u\{201\}$, and $d\{101\}$.

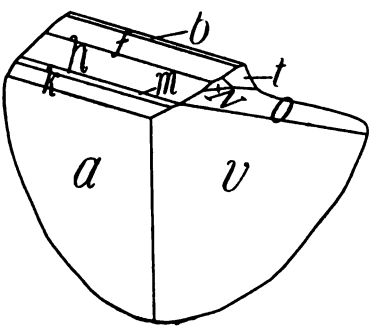

Fig. 3.

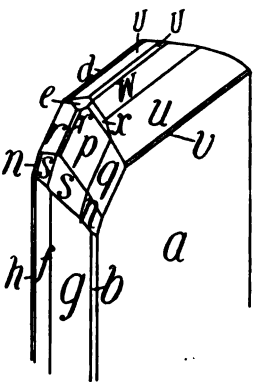

Fig. 4.

Crystals of Hutchinsonite.

In the principal pyramid-zone [100,011] the common and largest faces are those of the forms $o\{211\}$, $q\{322\}$, $p\{111\}$, and $r\{122\}$.

In the zone [100,021] the largest faces are those of the forms $t\{342\}$, $n\{121\}$, and $s\{142\}$ (cf. figs. 1, 3, and 4).

The face $\theta(825)$ is peculiar. It was only once observed, and in that case formed the only terminal face of the crystal. The natural supposition is that it is produced by some flat surface, which limited the growth of the crystal in that direction; on the other hand, it gives an unusually brilliant and distinct reflexion of the object-slit, which is not the case with pseudomorphous faces.

The remaining faces were quite minute, but gave measurable reflexions when the intensity of the image relative to the field of the telescope had been increased to the utmost.

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There is a good cleavage parallel to $a(100)$, but it cannot compare with the highly perfect cleavage of smithite.

Table II comprises the coordinates of the principal forms referred to the other faces of symmetry, $b(010)$ and $c(001)$, as origins.

TABLE II (HUTCHINSONITE).

Calculated coordinates of the principal forms with respect to b = (010) *and* c = (001) *as origins.*

$b = (010)$.

Form.	Indices.	Azimuth.	Distance.
U	102	77° 0′	90° 0′
r	122	,, ,,	53 40
s	142	,, ,,	34 18
d	101	65 12½	90 0
p	111	,, ,,	55 35
n	121	,, ,,	36 7
W	302	55 17	90 0
q	322	,, ,,	58 11
t	342	,, ,,	38 51½
u	201	47 16	90 0
o	211	,, ,,	60 58
N	221	,, ,,	41 54
v	301	35 49	90 0
Q	311	,, ,,	66 10
w	401	28 25½	90 0
a	100	0 0	90 0
F	210	,, ,,	50 37
l	740	,, ,,	46 57½
k	320	,, ,,	42 33
i	540	,, ,,	37 24½
m	110	,, ,,	31 28
h	340	,, ,,	24 39
f	120	,, ,,	17 0½
g	140	,, ,,	8 42

$c = (001)$.

Form.	Indices.	Azimuth.	Distance.
b	010	90° 0′	90° 0′
g	140	81 18	90 0
s	142	,, ,,	33 13½
f	120	72 59½	90 0
n	121	,, ,,	68 28
r	122	,, ,,	51 43
h	340	65 21	90 0
t	342	,, ,,	31 3
m	110	58 82	90 0
N	221	,, ,,	66 8½
p	111	,, ,,	48 30
i	540	52 35½	90 0
k	320	47 27	90 0
q	322	,, ,,	44 18
l	740	43 2½	90 0
F	210	39 23	90 0
o	211	,, ,,	39 54½
Q	311	28 35	32 22
a	100	0 0	90 0
w	401	,, ,,	61 34½
v	301	,, ,,	54 11
u	201	,, ,,	42 44
d	101	,, ,,	24 47½
U	102	,, ,,	13 0

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2. *Optical Characters.*

As might be anticipated from the colour of the crystals, the violet end of the spectrum is strongly absorbed, and, indeed, very little beyond the yellow is transmitted. Pleochroism is just discernible, but more by a slight variation in the intensity rather than in the hue of the transmitted light. The lustre is adamantine.

If a crystal be illuminated by monochromatic light and viewed between crossed nicols in the direction perpendicular to *b*(010), the resulting interference-figure is of the usual kind given by a biaxial crystal in the direction of the acute bisectrix. In red light the 'eyes' are visible in the field of view, but in sodium-light they cannot be seen, even if the plate be immersed in oil. The plane of the optic axes is parallel to *a*(100), and the usual test with a quartz-wedge reveals the double refraction as negative.

The crystal depicted in fig. 1 was mounted on the ordinary instrument for the measurement of the angle between the optic axes and dipped into pure methylene iodide, which was contained in a trough fitted with parallel glass sides. The angles between the optic axes in the oil were as follows:—

For C, $2H=35° 19'$, and for D, $2H=71° 58'$, where C and D are the Fraunhofer lines in the red and yellow portions respectively of the solar spectrum. As the wave-length of the illuminating light diminishes, the angle rapidly increases, and, since at the same time the intensity of the transmitted light markedly falls off, trustworthy observations in the green were found impracticable. The refractive indices of the liquid at the temperature, 18° C., of the observations are for C, 1·731, and for D, 1·740. From these values we find that $2E_r=63° 22'$, and that in sodium-light the optic axes are internally reflected.

The same crystal was mounted on a goniometer, and it was found that light could traverse the prism formed of the large face *g*(140) shown in the figure, and a small face of the same form lying at the back. The values corresponding to the position for minimum deviation furnish two of the principal indices. The refracted images lie very near together, and that experiencing the greater deviation is noticeably more strongly absorbed.

	Line C.		Line D.	
Angle of minimum deviation . .	37° 38′	37° 50′	39° 56′	40° 5′
Plane of polarization at right angles to	*a*(100)	*c*(001)	*a*(100)	*c*(001)
Corresponding refractive index . .	3·063	3·073	3·176	3·188
By calculation we have 2V . .	19° 44′		37° 34′	
And thence the third index . .	2·779		3·078	

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The optical constants for the lines C and D of the solar spectrum are then as follows:—

	Direction at right angles to			
	a(100).	*b*(010).	*c*(001).	2V.
Line C . .	3·063	2·779	3·073	19° 44′
„ D . .	3·176	3·078	3·188	37° 34′

The particular prism-angle was 17° 20′. Since an error of 2′ in its determination would involve an error of 3 units in the third place of decimals, probably the values given above for the first and third of the refractive indices may be considered accurate to that place. But it is otherwise with the second refractive index: an error of 1 unit in the third place of one of the other indices involves an error of 6 units in the third place of decimals in the case of the yellow light, and as much as 2 units in the second place of decimals in the other case.

It will be noticed that the values are slightly higher than those of the principal indices of proustite.

3. *Chemical Composition.*

The first analysis was made on the more definitely crystallized variety of hutchinsonite, which is transparent and deep-red in colour, and gives a brilliant scarlet streak. The material consisted mainly of measured crystals, but included some fragments which showed no crystal-faces. These fragments were deep-red and transparent and exhibited no perfect cleavage like that of smithite, but the possibility that some of them may have been trechmannite is not absolutely precluded. The crystals and fragments when broken up and examined under the lens were found to be not absolutely pure, but to contain needle-like inclusions and adhering minute fragments of black minerals. These impurities were detected by means of their black or chocolate-brown streaks, and were separated under the lens as far as possible, but traces of them were doubtless present in the material analysed.

The total amount of this variety of hutchinsonite, i.e. with scarlet streak, available for analysis was only about 18 milligrams. The analysis of so small a quantity of material, though intended primarily for the qualitative determination of the constituents, was conducted as carefully as possible by quantitative methods, and the percentage numbers thus obtained are given under I, although obviously not much reliance can be placed upon them. The mineral was decomposed in chlorine, and a separation thus at once effected between the volatile

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and the non-volatile chlorides. Decomposition took place readily in the cold, so that quite gentle heating sufficed to drive off completely the volatile chlorides. In the solution of the latter, only sulphur and arsenic were found. The sulphur was determined by precipitation as sulphate with barium chloride; and the arsenic by precipitation as sulphide. The latter was weighed and then oxidized by nitric acid. The total sulphur in the precipitated sulphide of arsenic was determined by precipitating the resulting sulphuric acid by barium chloride.

The non-volatile chlorides were found to consist of silver, lead, and thallium. The amount of chloride of silver left after treatment with nitric acid and water was comparatively small; the lead was precipitated and weighed as sulphate; and the thallium was separated as sulphide by precipitation with ammonium sulphide in alkaline solution, and then converted into sulphate. The solution gave a yellow precipitate with potassium iodide, and a brilliant green colour to the Bunsen-flame, showing in the spectroscope the characteristic green line. The percentage of thallium given below is that determined by deducting the chlorides of silver and lead from the weight of the non-volatile chlorides.

Two determinations of specific gravity, made with a 3 cc. pyknometer, on 27 milligrams gave the numbers 4·6 and 4·7 respectively.

The second analysis (the result of which is given under II) was made on the other variety of hutchinsonite, which occurs in minute, deep-red needles and has a deep cherry-red streak quite distinct from the scarlet streak of the first variety.

Of this second variety of hutchinsonite a somewhat larger amount of material (about 66 milligrams) was available for analysis. The minute tufts of needles detached from the dolomite were not absolutely pure. On separating the needles under the lens a little iron-pyrites in minute crystals and small fragments of a mineral giving a black streak were seen to be present. It spite of every care to remove these impurities, it is probable that traces of them were still present in the material analysed, but it is hardly conceivable that they could be in sufficient amount to account for the lead obtained in the analysis. In this analysis the same methods were employed as in the preceding one, except that the arsenic was precipitated by magnesia mixture. The solution of the volatile chlorides contained sulphur and arsenic and a little antimony; the non-volatile chlorides included copper, besides silver, lead, and thallium.

A determination of specific gravity made with a 3 cc. pyknometer on 0·0732 gram gave the number 4·6.

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The results of the two analyses are as follows:—

	I.	II.
Ag	9	2
Tl	25	18
Pb	12½	16
Cu	—	3
Fe	—	0½
As	30½	29½
Sb	—	2
S	26	26½
	103	97½

In analysis I, weight of material used = 0·0184 gram; weight of AgCl = 0·0022; $PbSO_4$ = 0·0034; $BaSO_4$ = 0·0349; As + S = 0·0102; $BaSO_4$ from As + S = 0·0333; AgCl + $PbCl_2$ + TlCl = 0·0107; TlCl (by diff.) = 0·0058 gram.

In analysis II, weight of material used = 0·0664 gram; weight of AgCl = 0·0016; $PbSO_4$ = 0·0153; CuO = 0·0025; $Mg_2As_2O_7$ = 0·0406; Fe_2O_3 = 0·0005; SbO_2 = 0·0015; $BaSO_4$ = 0·1286; AgCl + $PbCl_2$ + $CuCl_2$ + Fe_2Cl_6 + TlCl = ·0350; TlCl (by diff.) = 0·0142 gram.

The most probable formula suggested by the results of the analyses is $(Tl,Ag,Cu)_2S.As_2S_3 + PbS.As_2S_3$; but, considering the small amount of material dealt with and the somewhat unsatisfactory condition as regards freedom from impurities, the formula can only be regarded as provisional until larger amounts of material are available for analysis.

That hutchinsonite may be a double salt, as suggested by the formula, is probable, since it shows so little relationship crystallographically to either smithite ($Ag_2S.As_2S_3$), lorandite ($Tl_2S.As_2S_3$), or miargyrite ($Ag_2S.Sb_2S_3$).

4. *Summary of Characters of Hutchinsonite.*

Orthorhombic; $a : b : c = 1·6343 : 1 : 0·7549$. Crystals, prismatic in habit. Cleavage, a (100) good. Fracture, conchoidal. Brittle. Hardness, 1½–2. Specific gravity, 4·6. Lustre, adamantine. Colour and streak, scarlet-vermilion to deep cherry-red. Transparent to translucent. Optic axial plane parallel to a (100), acute bisectrix perpendicular to b (010); double refraction, negative and fairly strong. Pleochroism, weak. Composition, $(Tl,Ag,Cu)_2S.As_2S_3 + PbS.As_2S_3$.

II. Smithite.

The investigation of this species, to which Mr. Solly gave the name smithite, presented on the whole far less difficulty than was experienced

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in the case of hutchinsonite. Comparatively large fragments were obtained and no ambiguity, such as arose owing to the diversity in the coloration of the latter species, was encountered. The highly perfect cleavage and the characteristic interference-figure visible through the cleavage-face in convergent, monochromatic light provided an easy and satisfactory means of discriminating the species. It was, therefore, possible to collect an amount of pure material sufficient for a trustworthy determination of the chemical composition.

1. *Morphological Characters.*

Smithite is found usually in cleavage-fragments, which are sometimes as much as 3 mm. in length and 1 mm. in thickness, and well-formed crystals are uncommon. The finest crystal which has as yet come to light is shown in fig. 5; the approximately circular contour as seen in the drawing represents a diameter of nearly 1 mm. on the actual crystal. It lies in contact with a similar, but slightly inferior, crystal on a lump of sartorite. The crystals almost imperceptibly pass into the sartorite at the back, and no sharp division can be drawn between the red and the black minerals. These crystals were almost the first of the

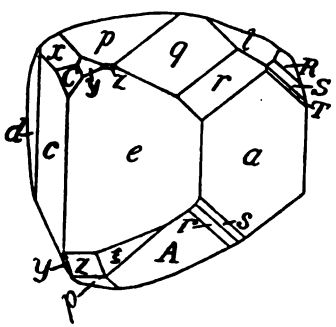

Fig. 5.

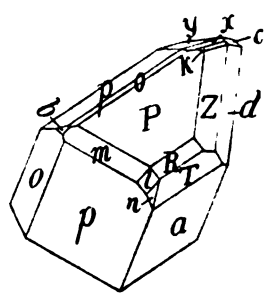

Fig. 6.

Crystals of Smithite.

red minerals to be discovered by Mr. Solly. Both were measured by him and the results of his measurements are recorded in his paper[1]. The crystal depicted in fig. 6 is much smaller and measures only 0·5 mm. in the greatest diameter. Several faces have been omitted on account of their smallness of size. The crystal was observed on a large cleavage-

[1] Loc. cit., p. 74.

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fragment of smithite found in 1904, which provided the material used in the chemical analysis. The crystal is of interest for several reasons. The habit is peculiar, and the development is unusually complete; the zone [*ac*] is inconspicuous and what is to all appearance the prism is really the principal pyramid-zone [*ap*]. No fewer than eight forms are represented, none of which have been observed on any other crystal; among them are the forms with complex symbols θ (759), G (0·1·10), H (3·1·10), and β (10·0·1). The rare zone [*ab*] too is well represented.

The ordinary appearance of the crystals of smithite is suggestive of a hexagonal crystal in which the basal plane is largely developed, due to the fact that the azimuthal angle (62° 56′) between the principal zones intersecting in the prominent cleavage-face approximates to 60° so far as the eye can judge. One cleavage-fragment had on the edge an irregular arrangement of small crystals of a deeper red, which proved on examination to be hutchinsonite. Another cleavage-fragment contained a number of small, opaque needles; one of them was with difficulty isolated, and the measurements in the prism-zone, which alone were possible, are in fair agreement with those required for stibnite.

The colour of smithite is a scarlet-vermilion, exactly like that of proustite, and the powder has the same hue. On prolonged exposure to strong sunlight the colour changes to an orange-red. Smithite is lighter in colour and more transparent than is usually the case with hutchinsonite. The associated minerals are sartorite, rathite, blende, iron-pyrites, realgar, orpiment, and hutchinsonite.

The three-circle goniometer was employed for the determination of the positions of the faces on all the measured crystals, and the cleavage-face, which was always conspicuous and gave a brilliant reflexion, was selected as origin. The measurements made on the best crystals, eight in number, are summarized in table III. Altogether fifty-seven forms have been observed, of which sixteen, viz. *a*, *c*, *e*, *d*, *s*, *r*, *q*, *B*, *p*, π, *o*, *T*, *S*, *Q*, *P*, ρ, have already been recorded by Mr. Solly[1]. The constants deduced by him, viz. $a : b : c = 2{\cdot}2309 : 1 : 1{\cdot}9657$; $\beta = 101° 12\frac{1}{2}'$ (78° 47½′), differ little from those given below.

[1] The form given by him as ($\bar{2}12$) should be (12$\bar{2}$).

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TABLE III (SMITHITE).

Measurements from a = (100).

$a : b : c = 2{\cdot}2206 : 1 : 1{\cdot}9570$; $\beta = 101° 12'$.

Form.	Indices.	Calculated values.		Observed Means.		Number.	Limits of Observations.	
		Azimuth.	Distance.	Azimuth.	Distance.		Azimuth.	Distance.
b	010	*	*	90° 0′	90° 0′	2	... 90° 14′	... 90°
μ	140	,,	88° 27′	,, ,,	88 38	1		
w	130	,,	81 18	,, ,,	81 37	1		
v	120	,,	77 4	,, ,,	77 18	2	... ...	77° 5′, 77
m	110	,,	65 20½	,, ,,	65 44	1		
l	320	,,	55 27	,, ,,	55 17	4	... ...	55 5 −55
n	210	,,	47 26½	,, ,,	47 16	2	... ...	46 57, 47
ν	520	,,	41 4	,, ,,	40 55	1		
J	44$\bar{1}$	82° 48′	−66 46	83 23	−65 50	1		
D	121	71 10	70 31	71 40	70 30	1		
U	61$\bar{1}$	*	−22 55	62 56	−22 52	1	62° 38′ −63 11	
T	51$\bar{1}$	,,	−27 6	,, ,,	−27 2	4	... ...	27 0 −27
S	41$\bar{1}$	,,	−32 54½	,, ,,	−32 50	4	... ...	32 48 −32
R	31$\bar{1}$	,,	−41 21	,, ,,	−41 14	2	... ...	41 13, 41
Q	21$\bar{1}$	,,	−53 58	,, ,,	−54 2	6	... ...	53 55 −54
P	11$\bar{1}$	,,	−72 19	,, ,,	−72 14	2	... ...	72 11, 72
σ	34$\bar{4}$	,,	−77 47	,, ,,	−77 56	1		
τ	23$\bar{3}$	,,	−79 40	,, ,,	−79 31	1		
ρ	12$\bar{2}$	,,	−83 28½	,, ,,	−83 24	1		
o	011	,,	84 51	,, ,,	84 50	2	... ...	84 45, 84
π	355	,,	71 27½	,, ,,	71 25	1		
p	111	,,	63 29	,, ,,	63 22½	5	... ...	63 16 −63
B	322	,,	54 53	,, ,,	54 47	3	... ...	54 45 −54
q	211	,,	47 46	,, ,,	47 34	8	... ...	47 20 −47
a	15·7·7	,,	45 59	,, ,,	45 58	2	... ...	45 56, 46
A	522	,,	41 57½	,, ,,	41 53	1		
r	311	,,	37 13	,, ,,	37 6	5	... ...	36 54 −37
s	411	,,	30 6	,, ,,	30 4	3	... ...	30 1 −30
t	511	,,	25 6½	,, ,,	25 10	1		
θ	759	47 28½	58 44½	48 13	58 46	1		
Ξ	413	33 7	−50 3	32 59	−50 26	1	32 55 −33 3	
Z	313	,, ,,	−59 35½	,, ,,	−59 35	2	... ...	59 31, 59
k	013	,, ,,	80 35	,, ,,	80 45	1		
x	113	,, ,,	67 28	,, ,,	67 24	3	... ...	67 20 −67
y	213	,, ,,	56 16½	,, ,,	56 16	4	... ...	56 14 −56
z	313	,, ,,	47 26	,, ,,	47 28	3	... ...	47 26 −47
ξ	413	,, ,,	40 32	,, ,,	40 26	2	... ...	40 21, 40

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TABLE III—*continued.*

Indices.	Calculated values.		Observed Means.		Number.	Limits of Observations.	
	Azimuth.	Distance.	Azimuth.	Distance.		Azimuth.	Distance.
21$\bar{4}$	26 4	−77 17	26 20	−77 14	2	25 50, 26 50	76 50, 77 38
215	21 22½	62 34	21 15	62 40	2	21 10, 21 20	62 30, 62 50
0.1.10	11 4	79 0	11 0	78 58	2	10 45 −11 15	78 56, 79 0
3.1.10	,, ,,	65 21	,, ,,	66 0	1		
40$\bar{1}$	*	−16 27	0 0	−16 28	1		
11.0.3	,,	−17 53½	,, ,,	−17 45	1		
50$\bar{2}$	,,	−26 1	,, ,,	−25 37	1		
20$\bar{1}$	,,	−32 1	,, ,,	−31 58	1		
50$\bar{3}$	,,	−37 34½	,, ,,	−37 26	1		
40$\bar{3}$	,,	−45 0	,, ,,	−44 53	2	... ...	44 20, 45 26
10$\bar{1}$	,,	*	,, ,,	−54 59	9	... ...	54 53 −55 6
001	,,	*	,, ,,	78 48	10	... ...	78 37 −79 0
308	,,	61 51	,, ,,	62 8	1		
102	,,	57 5	,, ,,	57 6	3	... ...	57 6 −57 6
505	,,	53 36	,, ,,	53 43	1		
101	,,	42 22	,, ,,	42 26	5	... ...	42 18 −42 35
301	,,	19 4	,, ,,	19 5	1		
501	,,	14 46	,, ,,	14 25	1		
10.0.1	,,	6 36	,, ,,	6 53	1		
100	,,	*	,, ,,	0 0	14		

Of the forms given above, the most prominent are *a* (100), *e* (101), *c* (001), and *d* (10$\bar{1}$) in the prism-zone, and *q* (211), *p* (111), *P* (1$\bar{1}$1), and *Q* (21$\bar{1}$) in the principal pyramid-zone. The forms *h* (102), *r* (311), *R* (31$\bar{1}$), and *l* (320) are occasionally represented by relatively large faces; but the remainder are quite small and often very minute.

There is a highly perfect cleavage parallel to *a* (100), which, as has been pointed out, provides a ready means of discriminating this species from hutchinsonite and trechmannite. The glistening of the cleavage-face readily catches the eye, and will reveal the existence of a thin skin of smithite on a lead sulpharsenite, which might otherwise have escaped detection.

In table IV are given the calculated coordinates of the principal forms with reference to the face of symmetry, *b* (010), as origin.

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TABLE IV (SMITHITE).

Calculated Coordinates of the principal forms referred to b=(010) *as origin.*

Form.	Indices.	Azimuth.	Distance.
Q	$\bar{2}11$	−32° 1½′	48° 56½′
d	$\bar{1}01$	−54 59	90 0
Z	313	,, ,,	61 53
P	$\bar{1}11$	,, ,,	31 57½
c	001	78 48	90 0
x	113	63 33	59 43
h	102	57 5	90 0
y	213	51 27	62 58½
e	101	42 22	90 0
z	313	,, ,,	66 16
p	111	,, ,,	37 10
q	211	26 37½	48 45
r	311	19 4	57 24½
a	100	0 0	90 0
l	320	,, ,,	34 33
m	110	,, ,,	24 39½
v	120	,, ,,	12 56

2. *Optical Characters.*

As in the case of hutchinsonite, very little of the violet end of the spectrum beyond the yellow is transmitted, and there is some indication of pleochroism. The lustre is adamantine.

If a cleavage-plate, which is parallel to *a* (100), be viewed in monochromatic, convergent light between crossed nicols a system of interference rings slightly out of centre may be seen; no rings are visible in white light. The figure is such as would be given by a biaxial crystal in the direction of one of the bisectrices, but no 'eyes' are visible,

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even in red light. A plate was mounted on an axial-angle instrument and it was found that the centre of the figure is inclined at an angle of 21° in air, equivalent to 6½° in the crystal, for sodium-light, and at an angle of 13° in air, equivalent to 4° in the crystal, for red (C) light, with the normal to *a* (100) in the obtuse angle (100 : 001). Even when the plate is dipped into pure methylene iodide the 'eyes' are invisible for any colour, however far the plate be rotated; but the curvature of the rings increases considerably and they become nearly circular in form. It is probable, therefore, that the optic axes were only just internally reflected, in which case the angle between the optic axes within the crystal for sodium-light would be about 65°. At any rate, there seems no doubt that it is the acute bisectrix which is so nearly at right angles to *a* (100), and the plane of the optic axes is therefore parallel to *b* (010). The usual test by means of a quartz-wedge shows that the character of the double-refraction is negative.

Unfortunately, none of the crystals of smithite examined were favourably enough developed for the determination of the principal indices of refraction; indeed, it rarely happens that any zone extends completely round a crystal. Further, they are too small or too thin to permit of the grinding of artificial faces for the purpose. It was possible on the crystal shown in fig. 6 to observe the light refracted through the prism formed by faces of the forms *o* (011) and *p* (111), and the measurements of the angles of minimum deviation lead to the values 3·18 and 3·36 for sodium-light, whence is obtained 3·27 as an approximate value for the mean refractivity, slightly higher than that found for hutchinsonite.

3. *Chemical Composition.*

For the analysis of smithite much more satisfactory material was available than in the case of hutchinsonite. It consisted of a fairly large cleavage-fragment of the mineral, part of which was perfectly pure and free from inclusions. A preliminary analysis was made on about 50 milligrams of less pure material containing minute, dark, needle-like inclusions. The mineral was decomposed in chlorine and the analysis was conducted by the same methods as in the case of hutchinsonite. The result of this preliminary analysis, made on 0·0502 gram, was as follows:—Ag, 40; Pb, 1; Cu, 2; As, 25½; S, 26½; total, 95·0 per cent.

For the second analysis, made on perfectly pure material, as much as a decigram was available. The result was as follows:—

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			Atomic ratios.	Calc. for $AgAsS_2$.
Ag	...	43·9	0·407	43·69
As	...	28·9	0·385	30·36
Sb	...	0·4	—	—
S	...	26·0	0·812	25·95
		99·2		100·00

Weight of material used = 0·1076 gram; weight of AgCl = 0·0626; $BaSO_4$ = 0·2087; $Mg_2As_2O_7$ = 0·0643; SbO_2 = 0·0005 gram.

Specific gravity, as determined with a 3 cc. pyknometer on 0·1128 gram of pure material, = 4·88.

The numbers obtained agree very closely with the simple formula $AgAsS_2$ or $Ag_2S.As_2S_3$.

4. *Summary of Characters of Smithite.*

Monoclinic; $a : b : c = 2·2206 : 1 : 1·9570$; $\beta = 101° 12'$. Crystals, hexagonal in habit, tabular and occasionally modified. Cleavage, a (100), highly perfect. Fracture, conchoidal. Brittle. Hardness, 1½–2. Specific gravity, 4·88. Lustre, adamantine. Colour and streak, scarlet-vermilion, altering to orange-red on exposure. Transparent. Optic axial plane parallel to b (010); acute bisectrix inclined at 6½° (Na) and 4° (Li) to normal to a (100) in the obtuse angle (100 : 00$\bar{1}$); 2E about 65°. Double refraction, negative and fairly strong. Pleochroism, weak. Mean refractive power, 3·27 approximately. Composition, $Ag_2S.As_2S_3 = AgAsS_2$.

III. Trechmannite.

Of these red minerals, by far the rarest, at the present time, is the third species, to which the name trechmannite has been assigned by Mr. Solly. In consequence, it has not been possible to carry out the investigation of its characters to the same completion as in the case of the two companion species just considered; and, moreover, so little material could be spared for analysis, that even a complete qualitative determination of the chemical composition was impracticable. As has already been stated at the beginning of this paper, the discovery of this new mineral was made by Mr. Solly on an examination of the specimen placed at his disposal by Dr. Trechmann; none of the crystals on it, however, were sufficiently well developed for a satisfactory

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determination of the morphological characters. In 1904 a single good crystal (fig. 7) with dull, but plane, faces was found; in the following year (1905) a pair of brilliant crystals in nearly parallel position, the larger of which is illustrated in fig. 8, came to light; and finally, last summer Mr. Solly secured five specimens, on each of which were a few small, well-developed crystals.

The satisfactory discrimination of trechmannite from the lighter-coloured variety of hutchinsonite requires the crystal to have a sufficient number of faces for the recognition on goniometrical examination of some characteristic angle. If, however, the crystal be intimately associated with tennantite ('binnite') it is in all probability trechmannite.

1. *Morphological Characters.*

Trechmannite has a remarkable predilection for the black and metallic-looking tennantite ('binnite') characteristic of this locality, and, indeed, all the good crystals which have been observed were found springing from this mineral. The crystals are always small, and, as will be pointed out in further detail below, they are frequently corroded in parts.

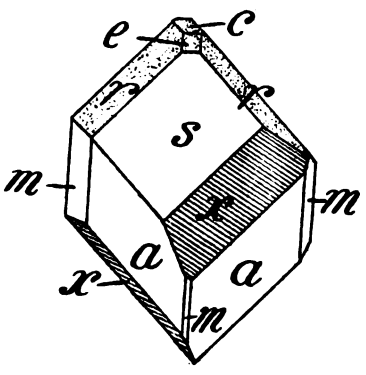

Fig. 7.

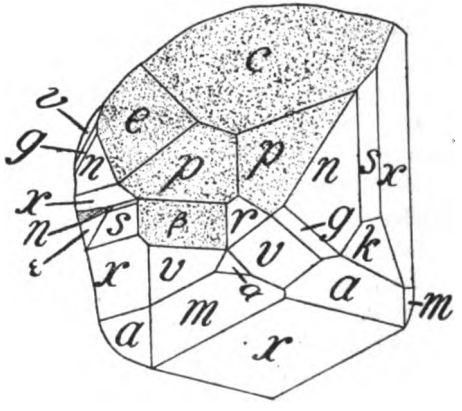

Fig. 8.

Crystals of Trechmannite.

For the determination of the morphological constants the measurements made on the five best crystals observed were alone utilized.

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Crystal 1 (fig. 7) was found by Mr. Solly[1] and has already been described by him. Part of the crystal of tennantite ('binnite') on which it was found had to be cut away in order to complete the measurements. It is the largest crystal as yet found and measures 1 mm. in the greatest diameter; the remaining crystals do not exceed 0·7 mm. All the faces are dull, but mostly give distinct reflexions of the object-slit with the exception of those (o, e, and r) stippled in the drawing, which were so much corroded that no measurements were possible. The edges between the faces are, however, so distinct as to leave no doubt regarding the identification of the faces. Each face of the rhombohedron of the third order, x, is striated parallel to its intersection with that face of the contiguous form which makes the smaller angle with it.

Crystal 2 (fig. 8) is the larger of a pair in nearly parallel position, which were found in 1905 and have likewise been measured by Mr. Solly.[2] The second individual lies to the right, when viewed as depicted in the figure. Here again, certain faces (o, e, p, and β) are corroded, and no trustworthy measurements of them were possible. It is curious that the faces closely adjoining are bright, even up to the edge or edges separating them from those corroded. On the left the crystal is broken and certain faces (x and n) are repeated on either side; a re-entrant angle is, of course, formed where the faces n and x on opposite sides meet. The crystal is most irregularly developed and the prism is by no means the most conspicuous zone.

Crystal 3 (fig. 9) was found last summer; a small crystal of iron-pyrites is partially embedded in it at the back. Again, certain faces (p, r, and η) are corroded, and in this case the edges bounding them are indistinct, so that the identification of them is uncertain. The crystal is, moreover, broken at the top. The prism-zone is unusually conspicuous, and the faces of the form a are striated parallel to the edge of the prominent zone [*azxam*]. These striae, together with the considerable development of faces below as well as above the prism-zone, reveal clearly the nature of the symmetry, to which we recur below.

Crystal 4 (fig. 10) also was found last summer. It surpasses all that have yet been observed as regards the brilliancy of the reflexions and the number of the faces present; in all thirty-nine distinct faces were observed, many of which are too minute to be reproduced in the

[1] Loc. cit., p. 75.
[2] Loc. cit., p. 189.

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drawing. There are no signs of corrosion. The stippling in the figure represents a gap in the crystal, on both sides of which appears a face of the form *c*.

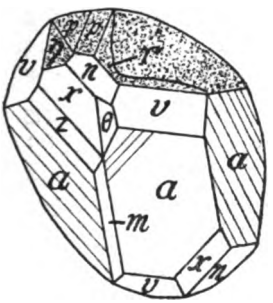

Fig. 9.

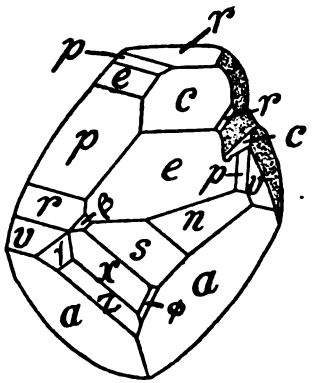

Fig. 10.

Crystals of Trechmannite.

Crystal 5, likewise found last summer, is very imperfect and possesses few faces other than those in the prism-zone. The faces of the form *a* are striated parallel to the prism-edge.

The illustrations represent as faithfully as possible the actual crystals.

The colour of trechmannite is a scarlet-vermilion, and that of its streak is the same. There is a good cleavage parallel to *r* (100), and Mr. Solly[1] has noticed another perpendicular to the edge of the prism-zone. The associated minerals are, in addition to tennantite ('binnite'), seligmannite, blende, iron-pyrites, and a colourless to light-greenish mica (fuchsite).

Trechmannite belongs to the hexagonal-alternating, or diplohedral, class of the rhombohedral system[2], which includes such important species as ilmenite and phenacite. A study of fig. 9 shows clearly that the crystal possesses a centre of symmetry and a trigonal axis, which together are equivalent to a hexagonal-alternating axis, but is devoid of planes of symmetry and digonal axes. The zone [*azxsn*] is always prominent, and the form *x* is one of the most conspicuous (cf. figs. 7 and 8).

[1] Loc. cit., p. 75.

[2] The symmetry was at first incorrectly stated (Nature, 1905, vol. lxxi, p. 574) to be that of quartz on the examination of an incompletely developed crystal, and was so given by Mr. Solly, loc. cit., p. 190.

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TABLE V (TRECHMANNITE).

Measurements from c = (111) = (0001).

Rhombohedral, diplohedral; $a:c = 1:0{\cdot}6530$.

Form.	Indices.		Calculated Values.		Observed Means.		Number.	Limits of Observations.	
	Rhombohedral.	Hexagonal.	Azimuth.	Distance.	Azimuth.	Distance.		Azimuth.	Distance.
c	111	0001	... ...	0° 0′	... ...	... ...	4		
m	2̄11	10$\bar{1}$0	0° 0′	90 0	0° 0′	90° 0′	11		
F	32̄1	14$\bar{5}$0	10 53½	,, ,,	10 11	,, ,,	1		
d	72̄5	13$\bar{4}$0	13 54	,, ,,	13 23	,, ,,	1		
D	41̄3	25$\bar{7}$0	16 6	,, ,,	16 10	,, ,,	3	16° 0′ – 16° 19′	
a	10̄1	11$\bar{2}$0	30 0	,, ,,	30 0	,, ,,	13	30 15	
H	12̄2	10$\bar{1}$5	0 0	8 34½	0 0	9 0	1		
G	13̄3	20$\bar{2}$7	,, ,,	12 9½	,, ,,	12 10	1		
e	01̄1	10$\bar{1}$2	,, ,,	20 39½	,, ,,	20 41	3	... ...	20° 36′ – 20° 48′
s	1̄11	20$\bar{2}$1	,, ,,	56 33	,, ,,	56 28½	11	... ...	56 24 – 56 37
φ	32̄2	50$\bar{5}$1	,, ,,	75 9	,, ,,	75 27	1		
r	10̄0	10$\bar{1}$1	,, ,,	37 1	,, ,,	37 2	5	... ...	36 57 – 37 11
a	31̄1	40$\bar{4}$1	,, ,,	71 39½	,, ,,	71 38½	2	... ...	71 37, 71 40
θ	17̄.12.14	2.29.3$\bar{1}$.9	3 19	68 20	3 8	68 15	1		
k	76̄5	1.12.$\bar{1}$3.4	3 58½	67 3	4 1	66 55	1		
λ	65̄6	1.11.$\bar{1}$2.5	4 18½	60 6	4 38	60 19	1		
n	23̄2	14$\bar{5}$3	10 53½	49 2	10 59	49 3	9	10 37 – 11 4	48 58 – 49 9
x	21̄2	13$\bar{4}$1	13 54	69 48½	13 58	69 50	14	13 48 – 14 9	69 45 – 69 59
V	53̄1	26$\bar{8}$1	,, ,,	79 35	13 57	79 32	1		
δ	03̄7	4.9.$\bar{1}$3.4	17 29	65 18	17 40	65 13	1		
ε	8.5.$\bar{1}$3.11	6.18.$\bar{1}$9.8	18 9	57 42	18 13	57 44	1		
v	21̄0	12$\bar{3}$1	19 6½	63 22½	19 8	63 25	13	18 58 – 19 15	63 16 – 63 36

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z	318	2461	19 6½	75 56	19 7	75 56	4	18 54 – 19 12	75 40 – 76 10
g	325	3584	21 47	52 50½	21 56	52 55½	2	21 58, 21 59	52 50, 53 1
ζ	14.10.1	3581	,, ,,	79 16	21 39	79 28½	2	21 38, 21 40	79 20, 79 27
η	124	2355	23 25	33 19	23 30	33 10	1		
β	411	2354	,, ,,	39 24½	23 14	39 22	1		
χ	430	3471	25 17	77 42					
γ	541	4592	26 19½	71 14½	26 9	71 40	1		
p	012	1123	30 0	23 31½	30 0	23 40	4	30 4	23 29 – 23 55

TABLE VI (TRECHMANNITE.)

Measurements from a = (101) = (1011).

Form.	Indices.		Calculated Values.		Observed Means.		Number.	Limits of Observations.	
	Rhombohedral.	Hexagonal.	Azimuth.	Distance.	Azimuth.	Distance.		Azimuth.	Distance.
z	313	2461	*	17° 43½′	52° 59′	17° 39½′	5	52° 52′ – 53° 4′	17° 33′ – 17° 40′
x	212	1341	,,	25 37	,, ,,	25 33	12	... ...	25 3 – 25 47
s	111	2021	,,	43 48	,, ,,	43 44	12	... ...	43 11 – 43 58
n	232	1453	,,	55 11	,, ,,	55 9	5	... ...	55 0 – 55 20
r	010	1011	,,	*	,, ,,	90 0	5	... ...	90 5
c	111	0001	90° 0′	90 0					
χ	304	3471	69 20½	13 9½	69 18½	12 52½	2	69 7 – 69 29	12 45, 13 0
v	102	1231	,, ,,	28 37	,, ,,	28 36	4	... ...	28 30 – 28 43
r	001	1011	,, ,,	58 34½	,, ,,	58 32	4	... ...	58 29 – 58 38
p	102	1123	,, ,,	78 29	,, ,,	78 24	4	... ...	78 15 – 78 33
e	101	1012	,, ,,	*	,, ,,	90 0	2	... ...	90 3

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All four crystals were measured on the three-circle goniometer from the face $c=(111)=(0001)$ as origin, and in the three cases where this face was corroded the crystals were set up by means of the prism-zone. In table V are given the means of the observed values and the calculated values of the coordinates. The latter values have been computed from the mean of the azimuths of the prominent zone $[azxsn]$, viz. 52° 59′ (see table VI). The axial ratio thus determined, $a:c=1:0{\cdot}6580$, differs little from that deduced by Mr. Solly from his measurements, viz. $a:c=1:0{\cdot}6556$.

In all, thirty forms have been observed, of which seven, viz. c, r, x, z, a, m, d, were noted by Mr. Solly; the form $f=\{325\}=\{17\bar{5}0\}$ recorded by him has not been noticed.

Further, on all four crystals, measurements were made of the faces in the two prominent zones intersecting in $a=(\bar{1}01)=(11\bar{2}0)$ from this pole as origin, and the means of the observations together with the corresponding calculated values are given in table VI.

The characters of the various forms are as follows:—

$c=\{111\}=\{0001\}$ usually small and frequently corroded.

$m=\{\bar{2}11\}=\{10\bar{1}0\}$ common, but small.

$a=\{\bar{1}01\}=\{11\bar{2}0\}$ common and large; striated on one crystal parallel to the edge of the zone $[azxsn]$ and on another parallel to the prism-edge.

$r=\{100\}=\{10\bar{1}1\}$ common, but small; sometimes corroded: a cleavage parallel to it.

$e=\{011\}=\{10\bar{1}2\}$ small: sometimes corroded.

$p=\pi\{012\}=\{11\bar{2}8\}$ not common, but occasionally large: sometimes corroded: the companion form $p_1=\pi\{021\}$ is also present.

$v=\pi\{2\bar{1}0\}=\{12\bar{3}1\}$ common, but small: the companion form $v_1=\pi\{20\bar{1}\}$ is also present.

$x=\pi\{\bar{2}12\}=\{18\bar{4}1\}$ common, and often very prominent: sometimes striated parallel to the intersection with the nearest face of the form m.

$z=\pi\{313\}=\{24\bar{6}1\}$ common, but small.

$n=\pi\{232\}=\{14\bar{5}3\}$ common, and fairly large.

The remaining forms were in all cases rare: on crystal 2 (fig. 8) $g=\pi\{325\}$ is represented by two faces, $k=\pi\{765\}$ by one, $a=\pi\{8\bar{1}1\}$ by two, $\beta=\pi\{4\bar{1}1\}$ by one corroded, and $\epsilon=\pi\{8{\cdot}5{\cdot}11\}$ by one, all of which faces are quite distinct though small; $\theta=\pi\{17{\cdot}12{\cdot}14\}$ appears as a definite face on crystal 3 (fig. 9); one of the corroded faces probably belongs to the

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form η, but for reasons given above there is some uncertainty. $\beta=\pi\{4\bar{1}1\}$ and $\gamma=\pi\{5\bar{4}1\}$ are each represented by one small, but distinct face on crystal 4 (fig. 10). Finally $V=\pi\{\bar{5}81\}$ and $\eta=\pi\{\bar{1}24\}$ are each represented by one small, but distinct face on crystal 5. The outstanding forms appeared as most minute faces. $\chi=\pi\{4\bar{3}0\}$ gave so faint a reflexion that approximate measurements in the zone [*avre*] alone were possible (see table VI).

2. *Optical Characters.*

As in the case of the previous species, very little above the red end of the spectrum is transmitted, and there is again some faint indication of pleochroism. The lustre is adamantine.

None of the crystals observed were suitably shaped for a determination of the optical constants, and the information obtained is very meagre. The mineral is highly refracting. On crushing up a small crystal, a splinter was seen which showed when viewed in convergent light between crossed nicols an indistinct uniaxial figure with negative double refraction.

3. *Chemical Composition.*

Qualitative tests made on a small fragment indicated the presence of silver and arsenic, and the absence of thallium. We may reasonably assume, therefore, that trechmannite is a sulpharsenite of silver.

4. *Summary of Characters of Trechmannite.*

Rhombohedral, diplohedral; $a:c=1:0{\cdot}6530$. Crystals, prismatic in habit often irregular; sometimes corroded in parts. Cleavage, *r* good, *c* distinct. Fracture, conchoidal. Brittle. Hardness, 1½–2. Lustre, adamantine. Colour and streak, scarlet-vermilion. Transparent to translucent. Double refraction, fairly strong; negative. Pleochroism, weak. Composition, probably a sulpharsenite of silver.

The formula found for smithite at once suggests that some obvious relation should subsist between its morphological characters and those of miargyrite, the corresponding sulphantimonite, such as obtains in the case of proustite and pyrargyrite; but, though both smithite and miargyrite are monoclinic in symmetry, there is no accord between the interfacial angles. Again, hutchinsonite contains thallium, but its morphological characters bear no resemblance to those of lorandite, the sulpharsenite of thallium. Finally, all three of the red minerals discussed in this paper differ completely from one another in their crystalline characters.

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Notes on some Bolivian minerals (Jamesonite, Andorite, Cassiterite, Tourmaline, &c.).

By L. J. Spencer, M.A., F.G.S.

With chemical analyses by G. T. Prior, M.A., D.Sc., F.G.S.
Assistants in the Mineral Department of the British Museum.

[Read November 13, 1906.]

Contents.

1. Analysis of crystallized Jamesonite.
2. Semseyite from Oruro.
3. New crystal-forms on Andorite: Systematic position of Andorite.
4. Chalcostibite from Oruro.
5. Augelite from Oruro and Tatasi.
6. New crystal-forms on Vivianite.
7. Tetrahedrite from Pulacayo mine, Huanchaca.
8. Regular grouping of Stannite and Tetrahedrite.
9. Axial ratios and analysis of Valentinite.
10. Cassiterite.
11. Tourmaline and Tourmaline-Hornfels from Tasna.
12. Fluorite.
13. Apatite.
14. Cupriferous Miargyrite from Tatasi.
15. Miargyrite from Aullagas.
16. Jarosite from Chocaya, Dept. Potosi.
17. Chalybite from Chorolque and Tatasi.
18. Enargite from Chorolque.

During the last twelve years I have communicated to this Society, often in collaboration with Dr. G. T. Prior, several papers descriptive of Bolivian minerals. These papers have dealt primarily with the species augelite, andorite, argyrodite, stannite, and chalcostibite, though many others have been examined and in some cases incidentally mentioned. The latter, as being of lesser general interest, or as not having led to sufficiently important results for separate publication, are now collected together in the present notes.

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The material available for examination has been acquired for the British Museum collection from various sources, and mainly during the last few years. Special mention may be made of several lots of specimens sent, at various times since 1894, for examination, and presented to the Museum by my friend Mr. Malcolm Roberts, A.R.S.M., a mine manager in Bolivia. Another collection, which may be specially mentioned, was brought from Bolivia by Sir Martin Conway, and presented by him in 1899 to the British Museum. A few choice specimens, notably a mass of pyrargyrite with crystals of argyrodite from Colquechaca, and a large mamillated mass of native copper coated with native silver from the Cobrizos mine at San Cristobal in province Nor-Lipez, have been presented by Señor F. Avelino Aramayo, formerly the Bolivian Minister in London. Thanks are also due to Mr. Thomas J. Hooper, General Manager to the Compañia Minera de Oruro, for a very large and magnificent specimen of andorite. Still more recently, several Bolivian specimens have been selected from the private collection of the late Theodor Hohmann (1848–1897), a mining engineer in Chili[1].

The specimens sent by Mr. Roberts are mainly from the silver mines at Tatasi and Portugalete in the province Sud-Chichas, and from the tin and bismuth mines at Tasna in province Nor-Chichas, department Potosi. From his own observation and from my notes on the specimens, Mr. Roberts[2] has published a brief account of the mineral-species which he has found at the former locality.

Sir Martin Conway's specimens are mostly from the silver and tin mines at Oruro, and from a tin and bismuth mine on the mountain of Huaina Potosi, near La Paz. A description of the twenty-three mineral-species represented in this collection of forty-six specimens has already been given[3] in some detail in the narrative of Sir Martin Conway's expedition; from this source such points as appear to be of general mineralogical interest are incorporated in the present notes.

[1] A brief description of this collection has been given by R. Pöhlmann, 'Die Mineralien-Sammlung des † Theodor Hohmann.' Verh. Deutsch. wiss. Ver. Santiago de Chile, 1899, vol. iv, pp. 75–86.

[2] M. Roberts, 'Minerals found in the silver lodes of Tatasi and Portugalete, Bolivia.' Trans. Inst. Mining and Metallurgy, London, 1899, vol. vii, pp. 91–3.

[3] L. J. Spencer, 'A description of the mineral specimens brought from Bolivia by Sir W. Martin Conway.' Pp. 343–66 in Sir Martin Conway, 'The Bolivian Andes, a record of climbing and exploration in the Cordillera Real in the years 1898 and 1900.' Harper & Brothers, London and New York, 1901.

The appendix of this volume also includes notes on other natural history specimens—the rock specimens were described by Professor T. G. Bonney (pp. 366–86)—but unfortunately there are no indications on the title-page nor

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1. Analysis of crystallized Jamesonite[1].

The specimens (Brit. Mus. nos. 80934, 83057, 83058) to be described are from the Cerro de Ubina[2], situated to the east of Huanchaca, and in the province Porco of the department Potosi. Tufts of jamesonite needles are disposed in the spaces between iron-pyrites crystals, which are present as veins in the massive, fibrous and radiating jamesonite forming the bulk of specimens. These veins of iron-pyrites consist of a granular aggregate of crystals interfering with each other's growth, and are of two kinds. The larger veins consist of fairly large and bright octahedra with small planes of the cube and pentagonal dodecahedron e {210}; it is in cavities between these crystals of iron-pyrites that most of the jamesonite needles are developed. The other veins are much narrower and consist of small cubes of iron-pyrites with small planes of the octahedron and e {210}. Imbedded in the massive jamesonite are patches of argentiferous tetrahedrite, and in cavities one or two minute crystals of native sulphur.

The needles of jamesonite reach a length of $\frac{1}{2}$ cm. and a thickness of $\frac{1}{2}$ mm.; they are deeply striated parallel to their length, and are usually closely aggregated. They are iron-black with a bright metallic lustre, and sometimes a slight iridescent tarnish. The streak is black and dull or in part shining; the hardness is $2\frac{1}{2}$. The needles are very brittle; they do not bend, but break along surfaces of good cleavage[3] perpendicular to their length.

Nineteen crystals were placed on the goniometer, but no really good measurements were obtained. The predominating form is the prism m {110}, and the needles have a rhomb-shaped cross-section; though sometimes one pair of parallel prism-faces is more largely developed and the crystals are then lath-shaped. Narrow faces of the forms n {120}, b {010}, and a {100} were also sometimes observed, but no terminal planes.

in the index of their existence. Figs. 1, 2, 3, and 10 in the present paper are reproduced from Sir Martin Conway's book, the electrotypes having been kindly supplied by the publishers.

[1] Compare this vol., p. 207.

[2] This occurrence has already been mentioned by A. Frenzel (Neues Jahrb. Min., 1893, vol. ii, p. 126). Here the locality is given incorrectly as 'Cerro de Uleina'.

[3] The statement of the cleavages of jamesonite given in the textbooks dates back to F. Mohs (1824). The basal cleavage, c(001), though good, can scarcely be described as perfect, and the others, m(110) and b(010), probably do not exist. The latter were not to be observed on any of the jamesonites I have examined; any apparent cleavage in these directions can be explained by the parallel aggregation of the acicular crystals.

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		Limits.	No. of edges.	Mean.	Calcd.
mm''' =	110 : 1$\bar{1}$0	78° 10′ – 79° 1′	4 (best)	78° 39′	78° 38′
		77° 32 – 81°	23 (all)	79 1	
mm' =	110 : $\bar{1}$10	101° 10 – 102° 6′	4 (best)	101 23	101 22
		100° – 103°	21 (all)	101 16	
mn =	110 : 120	17° – 22°	4	19½°	19 17
mb =	110 : 010	49° – 51½°	5	50 24	50 41
$m : c$ (cleavage)		85° – 94° 52′	14	89 49	90 0

The means, 78° 39′ and 78° 37′ (=180°–101° 23′) of the best readings, give the value for mm'''=110 : 1$\bar{1}$0 as 78° 38′, which agrees closely with Haidinger's determination[1] of 78° 40′ on needles of jamesonite from Cornwall. The axial ratio corresponding with this angle, 78° 38′, is $a : b = 1 : 0{\cdot}819$.

Two lots of material were collected for quantitative analysis. One lot consisted of isolated needles, many of which had been measured on the goniometer, together with some aggregates of needles taken from the cavities between the iron-pyrites crystals. The other lot was of massive material consisting of a more or less parallel aggregate of fibres, and showing a good end-cleavage. When examined under the microscope no impurities, such as iron-pyrites, could be detected. The method of analysis was the same as that previously adopted for andorite[2], and the following results, I for the crystals and II for the massive material, were obtained by Dr. G. T. Prior :—

	I.	Atomic ratios.			II.	Atomic ratios.		
S ...	20·52	0·6447	17·85		21·37	0·6714	18·50	
Sb ...	34·58	0·2889	8·00		34·70	0·2903	8·00	
Pb ...	41·18	0·2005	5·55		40·08	0·1952	5·38	
Fe ...	2·76	0·0496	1·37	7·03	2·79	0·0502	1·38	6·88
Cu ...	0·26	0·0041	0·11		0·22	0·0035	0·09	
Ag ...	0·01	0·0001	—		0·13	0·0012	0·08	
	99·26				99·29			
Sp. gr.	5·519				5·546			
Weight used	0·3932 gram				0·8997 gram			

English translation of F. Mohs's 'Treatise of Mineralogy', Edinburgh, 1825, vol. iii, p. 26; Edinburgh Journ. Sci., 1825, vol. ii, p. 374. The manuscript catalogue of the Allan collection, now in the British Museum, gives, under date 1824, this angle as 78° 30′, the entry referring to acicular Cornish crystals. The axial ratio corresponding with Haidinger's angle is erroneously given in the textbooks as $a : b = 1 : 0{\cdot}915$.

[2] Min. Mag., 1897, vol. xi, p. 290.

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The second of these analyses is the more reliable: in the first the lead sulphate included a little basic iron sulphate, and there may possibly have been a slight loss of sulphur.

These analyses do not lead to any simple formula. They correspond fairly closely with $7(Pb_{\frac{4}{5}}, Fe_{\frac{1}{5}})S.4Sb_2S_3 = R_7''Sb_8S_{19}$, the calculated percentage composition of which is given below :—

		$7(Pb_{4/5},Fe_{1/5})S.$ $4Sb_2S_3$.	$4PbS.$ $3Sb_2S_3$.	$3PbS.$ $2Sb_2S_3$.	$7PbS.$ $4Sb_2S_3$.	$2PbS.$ Sb_2S_3.
S	...	21·68	21·20	20·75	20·17	19·68
Sb	...	34·29	36·73	34·63	31·89	29·55
Pb	...	41·24	42·07	44·62	47·94	50·77
Fe	...	2·79	—	—	—	—
		100·00	100·00	100·00	100·00	100·00

The large amount of iron, which presents a difficulty in deducing a satisfactory formula, is not present as iron-pyrites, as the mode of occurrence of the mineral might suggest, since the amount of sulphur shown in the analyses is scarcely sufficient even for monosulphide. The atomic amount of sulphur required for Sb_2S_3, PbS, FeS, and CuS is 0·6855 in the second analysis, whilst the amount found is 0·6714. If the iron and copper are left out of account, the formula becomes $4PbS.3Sb_2S_3 = Pb_4Sb_6S_{13}$. As shown also by earlier analyses, quoted below, the iron appears, however, to be present in all cases to the amount of 2 to 3 per cent.

The observations recorded above were made in 1897, and their publication has been delayed in the hope of other material being found which would help to decide the question of the chemical formula of jamesonite, but, as yet, the material here described is the best available.

Several analyses have been published under the name jamesonite; but it must be remembered that many of these have been made on impure, massive material and ores, solely with the object of giving a specific mineralogical name; and that, in some cases, to make the results agree with the textbook formula, $2PbS.Sb_2S_3$, certain amounts of impurities (iron-pyrites, galena, stibnite) have been assumed to be present and have been deducted. Only those analyses which have been made on material known to be jamesonite by the presence of the basal cleavage can be of any value in deducing a formula for this mineral: such analyses are collected together below.

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	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
S	22·15	22·53	[23·01]	21·78	21·52	20·86	21·35	21·75
Sb	34·40	34·90	33·47	32·62	33·03	31·94	not det.	32·00
Pb	40·75	39·45	40·35	39·97	40·18	42·79	40·47	39·05
Fe	2·30	2·65	2·96	3·63	not det.	2·83	2·68	2·00
Cu	0·13	0·19	0·21	—	—	1·01	0·50	3·45
Zn	—	—	—	0·42	0·36	1·84	5·82	0·62
	99·73	99·72	100·00	99·48[1]	—	101·27	—	100·41[2]
Sp. gr.	—	—	—	5·616		5·478–5719		5·54

I–III. H. Rose (Ann. Chem. Phys. (Poggendorff), 1826, vol. viii, p. 100; 1829, vol. xv, p. 470). Cornwall.

IV and V. F. Schaffgotsch (ibid., 1836, vol. xxxviii, p. 403). Valencia de Alcantara, Spain. V, the mean of three partial analyses.

VI and VII. C. Rammelsberg (C. Rammelsberg and C. Zincken, ibid., 1849, vol. lxxvii, p. 242). Selkethal, Harz. Different figures are given in Rammelsberg's Min.-Chem., 1860, p. 71; 1875, p. 92.

VIII. M. Siewert (A. W. Stelzner, Min. Petr. Mitt. (Tschermak), 1878, p. 247). Sierra de los Angulos, Argentina.

These, then, are the only analyses that can be given for what is certainly known to be jamesonite, and one of the analyses now published is the only one that has been made on measured crystals of this mineral.

Rose's analyses show a slight excess[3] of sulphur over that required for RS and Sb_2S_3; he consequently deducted the iron as iron-pyrites and deduced the formula $8PbS.2Sb_2S_3$. Schaffgotsch, to make his analyses agree with this formula, had to deduct 8½ per cent. of impurities (ZnS, Bi_2S_3, FeS); there being no excess of sulphur, the iron was assumed to be present as pyrrhotite. Rammelsberg deducted from his analysis (VI) FeS_2, ZnS, and 6 per cent. of Sb_2S_3, and gave the formula $2PbS.Sb_2S_3$. Stelzner, although he mentions that the material analysed was apparently pure, also deducted iron (as mispickel, iron-pyrites, and copper-pyrites), and deduced the formula $37PbS.AgS.CuS.26Sb_2S_3$.

All these analyses show the presence of about 2 to 3 per cent. of iron,

[1] Including Bi 1·06.

[2] Including Ag 1·34, As 0·20.

[3] The excess is, however, not sufficient for iron-pyrites.

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and taking this into account, they agree fairly well with the formula $7(Pb\frac{4}{5}, Fe\frac{1}{5})S.4Sb_2S_3$, suggested above.

Sulphantimonites of lead are of frequent occurrence in Bolivia and have often been referred to jamesonite, but only rarely have they been definitely determined to belong to this species. In the account of Sir Martin Conway's collection I have described [1] specimens of crystallized jamesonite from Oruro, Bolivia; these were determined by measurement of the prism-angle (about 79°) and by the presence of a good basal cleavage. Other specimens, previously referred to zinckenite [2], have since been shown by these characters to be jamesonite: they are from Machacamarca near Potosi and from the Socavon de la Virgen at Oruro.

2. Semseyite from Oruro.

The specimen here described was sent to me by the Foote Mineral Company, of Philadelphia, for determination. The crystals of semseyite are iron-black in colour and have a bright metallic lustre. They are aggregated in rosette-like groups, so that the individual crystals, which reach to 5 mm. across, are not very distinctly developed. The faces of the twisted crystals are so curved and irregular, with step-like and drusy growths, that it was impossible to obtain any reliable measurements of the angles between them. In general habit and appearance, however, the crystals are exactly like those of plagionite and semseyite from Wolfsberg in the Harz. The basal plane $c\{001\}$ and the pyramid $n\{111\}$ can be distinguished, and parallel to the faces of the latter there are good cleavages. Measurement of several of the most likely crystals gave results varying between 40° and 45° for the angle between c and n. These measurements are not sufficient to distinguish between plagionite and semseyite, since in the former $cn = 41°8'$ and in the latter $cn = 46°35'$ [3].

In order to determine to which member (plagionite, heteromorphite or semseyite) of the plagionite group of minerals the crystals belong, it therefore became necessary to determine their specific gravity and the percentage of lead they contain. A small amount (0·16 gram) of the crystallized material was collected, and was analysed by Dr. G. T. Prior with the following results:—

[1] Loc. cit., p. 359.
[2] Min. Mag., 1895, vol. xi, p. 23; 1897, vol. xi, p. 299.
[3] Min. Mag., 1899, vol. xii, p. 55.

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		Atomic ratios.
Pb . . .	52·9 . . .	0·256
Ag . . .	1·6 . . .	0·015
Sb . . .	24·8 . . .	0·206
S . . .	18·7 . . .	0·583
	98·0	
Sp. gr. . .	5·82	

These results point conclusively to semseyite[1]. The presence of silver is noteworthy, since this element has not previously been detected in minerals of the plagionite group. It is possible, however, that the silver may be present as andorite intermixed with the semseyite, although no andorite could be detected on the specimen. Another point brought out by the analysis is that the mineral is rather more basic than the two semseyites previously analysed: here, $(Pb, Ag_2) : Sb = 1{\cdot}28 : 1$; whilst in semseyite from Hungary and the Harz, $Pb : Sb = 1{\cdot}15 : 1$ and $1{\cdot}05 : 1$ respectively.

The matrix of the specimen consists of another species of sulphantimonite of lead, the structure of which is fibrous. The compact aggregation of fibres, which are either radially or confusedly arranged, is mixed with some massive iron-pyrites and a little kaolin. On the free surface of the specimen the fibres have the form of delicate, flexible hairs, which can be bent without being broken, and are therefore *plumosite*[2]. The surface of this felted mass of plumosite needles is curiously marked with smooth, concave depressions, rather suggesting that the mineral had been partly dissolved. The semseyite crystals occur only on this surface and are partly embedded in the feathery plumosite. With them is a little galena, which often forms the nucleus of the rosettes of semseyite crystals.

Although sulphantimonites of lead are of common occurrence in Bolivia, they appear to belong usually to the fibrous, orthorhombic species, especially jamesonite and plumosite; and none of the monoclinic species of the plagionite group have been hitherto determined from this region. It is possible that one or more of the eight varieties of 'antimonial galena' mentioned by D. Forbes[3] from the department of La Paz may belong to the plagionite group, but his descriptions are too brief to enable one to judge of this.

[1] Compare the table of analyses and sp. gr. given in Min. Mag., vol. xii, p. 65.

[2] Compare this vol., p. 207.

[3] Phil. Mag., 1865, ser. 4, vol. xxix, p. 10. In an earlier paper (Quart. Journ. Geol. Soc., 1861, vol. xvii, p. 61) Forbes gives the name plagionite in a list of minerals occurring in the Bolivian mineral-veins.

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Semseyite has previously been recorded only from Felsöbánya and Rodna in Hungary and from Wolfsberg in the Harz.

3. New crystal-forms on Andorite[1].

Andorite is, at present, known from only two localities, namely, Felsöbánya in Hungary and Oruro in Bolivia. At the latter it seems to be rather plentiful, and there are now several specimens representing this occurrence in the British Museum collection. Crystals were detected on four of the specimens from Oruro presented by Sir Martin Conway; and the following description is based mainly on that specimen on which the best crystals of stannite[2] were found.

This specimen (Brit. Mus. no. 84686), from the San José mine at Oruro, consists of groups of radiating, prismatic crystals of mispickel, encrusted with crystals of andorite, stannite, and iron-pyrites. The bright crystals of andorite are sometimes doubly terminated, and the largest is about 4 mm. long. In habit they are somewhat tabular parallel to the macropinacoid $a\{100\}$. Pyramids and domes are numerous, but are very irregularly developed, so that the crystals are usually distorted and unsymmetrical in appearance. In figs. 1 and 2 the crystals are idealized by drawing all the faces of the same form of equal size.

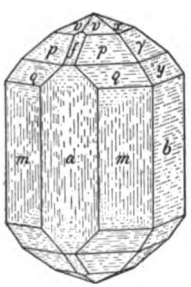

Fig. 1.

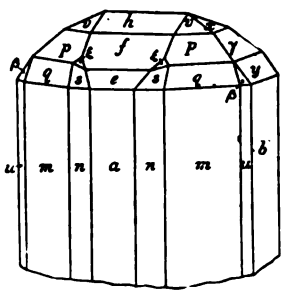

Fig. 2.

Andorite from Oruro, Bolivia.

A conspicuous feature of the crystals is the deep striation of all the faces (fig. 1); in some zones the striations are often so deep and numerous as to render the crystal almost unsuitable for measurement. The pyramids, domes, the brachypinacoid $b\{010\}$, and the prisms $u\{130\}$, $g\{250\}$, and $k\{120\}$ are all striated horizontally; the macro-

[1] Compare Min. Mag., 1897, vol. xi, p. 286.

[2] Min. Mag., 1901, vol. xiii, p. 55.

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pinacoid $a\{100\}$ and the remaining prisms are striated vertically, with a few horizontal striae, especially on $a\{100\}$, giving rise to rectangular markings. On the goniometer, these striated zones give continuous bands of reflected images, limited, however, between certain points: in the prism-zone between $a(100)$ and $l(230)$; in the macrodome-zone between $a(100)$ and $h(102)$; in the brachydome-zone between $b(010)$ and $x(011)$ or $w(035)$; and in the several pyramid-zones $[hk0, 001]$ the bands are limited between the zones [100, 010] and [102, 010]. As the summit of a crystal is approached, the striations become less numerous and the bands of reflected light much fainter. The pyramid-zones showing such bands of light are:—[310, 001], [210, 001], [110, 001], [230, 001], [120, 001], and [130, 001]; of these it may be remarked that no pyramidal faces have yet been recorded in the zone [230, 001].

Three crystals were measured on the goniometer, and the following thirty-five forms noted:—

Pinacoids:	$a\{100\}$	$b\{010\}$	$c\{001\}$.			
Prisms:	$n\{210\}$	$m\{110\}$	$l\{230\}$	$k\{120\}$	$g\{250\}$	$u\{130\}$.
Macrodomes:	$h\{102\}$	$\sigma\{203\}$	$f\{101\}$	$e\{302\}$.		
Brachydomes:	$w\{035\}$	$x\{011\}$	$\gamma\{021\}$	$y\{031\}$	$\eta\{041\}$.	
Pyramids:	$\xi\{312\}$	$s\{211\}$	$A\{321\}$	$v\{112\}$	$C\{243\}$?	$\omega\{132\}$
				$\chi\{223\}$	$\delta\{364\}$	$\beta\{131\}$
				$p\{111\}$	$r\{121\}$	$E\{261\}$.
				$q\{221\}$	$\epsilon\{362\}$	
				$\rho\{331\}$	$D\{241\}$	
				$B\{441\}$		

The forms present on each crystal were:—

No. 1. *ab*, *nmlkgu*, *xγy*, *s*, *qρB*, *ϵD*, *βE*; also deeply striated, indefinite macrodomes.

No. 2. *abc*, *nmlu*, *wxγyη*, *s*, *vχγqρB*, *δϵ*; also indefinite macrodomes.

No. 3. *abc*, *nmlku*, *hσfe*, *xγ*, *ξ*, *s*, *A*, *vχpqB*, *Cr*, *ωβ*.

The basal plane, $c(001)$, is present on crystal No. 2 as a very small face truncating the brachydomes, and it is faintly curved and striated parallel to the brachyaxis [100]; on crystal No. 3 it truncates the macrodomes, and is curved and striated parallel to [010].

Of the forms given above, $u\{130\}$ has not before been observed on Bolivian crystals, and $g\{250\}$ has been observed only by Brögger. The following are new for the mineral:—

$w\{035\}$. Two narrow, bright faces, faintly striated horizontally.

$\eta\{041\}$. Only as bright striae; observed twice.

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$\xi\{312\}$. Two small bright faces striated horizontally; in the zones [112, 100], [101, 110], [302, 010], and [310, 001][1].

$A\{321\}$. Two narrow planes on the edges of the horizontal striae on $a(100)$; in the zones [101, 110], [100, 021], and [320, 001][1].

$B\{441\}$. Small planes, sometimes rather wide; deeply striated horizontally. On all three crystals.

$C\{243\}$?. Two small planes in the striated zones [120, 001]; the brightest portion of the bands fall just on either side of the zone [203, 010].

$D\{241\}$. A fairly large plane, deeply striated horizontally; in the zones [120, 001] and [211, 010].

$E\{261\}$. A small plane deeply striated horizontally and giving no bright image in the reflected band of light; in the zones [130, 001] and [211, 010].

The following are the angular measurements establishing the new forms :—

		Calculated.	Measured.
wb,	035 : 010	75° 1½′	74°22′, 75°
ηb,	041 : 010	29 17	30°, 29½°
ξe,	312 : 302	9 0½	9°7′
ξa,	312 : 100	46 3	46°
	312 : (310)[1]	44 39	44°42′
Aa,	321 : 100	34 9	34°1′
	321 : (320)[1]	24 46	24°, 25°
Bm,	441 : 110	17 27	17°38′, 17°18′, 18°8′, 17°24′
Dk,	241 : 120	24 17	24°
	241 : (201)[1]	47 10	47°16′
	261 : (201)[1]	58 16½	58°28′

On a second specimen (no. 84685), also from the San José mine at Oruro, are several small crystals of andorite encrusting the walls of cavities in massive argentiferous tetrahedrite. It is possible that some of the massive material is actually andorite since it closely resembles the crystallized material in appearance. All the fragments tested, however, contained copper, but the crystals when treated with nitric acid on a microscope-slide showed no indications of the presence of copper. The crystals are 1–2 mm. in length, and are bright, but

[1] The faces (310), (320), and (201) were not present on the crystals, but their positions were fixed approximately by means of rough graduations on the crystal adjustment arcs of the goniometer.

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deeply striated in the manner described above. On one crystal, pyramid-planes were noticed in each of the eight octants. The forms determined by the goniometrical measurement of one crystal were:—*abc*, *nml*, *hfe*, $\pi\{032\}\gamma y$, *vpq*.

Mention may here be made of a magnificent specimen (no. 84659) of andorite presented to the British Museum in 1899 by Mr. Thomas J. Hooper, General Manager of the Compañia Minera de Oruro. This is from the Itos Atocha mine at Oruro; it measures roughly $30 \times 25 \times 7$ cm. and weighs 48½ pounds. It formed part of a vein of iron-pyrites, which mineral is frequently crystallized in bright cubo-octahedra with small planes of the pentagonal dodecahedron $e\{210\}$. On this iron-pyrites, in cavities and on the surface, is deposited the andorite, numerous large crystals of which cover the whole face of the vein, or free crystallized surface of the specimen. The cubo-octahedra of iron-pyrites and the crystals of andorite on this surface are much corroded, and deposited on them, as a later growth, are one or two small cubes of iron-pyrites and a few small groups of flexible hairs of plumosite. On the back of the specimen is some pale yellowish clay.

The large crystals of andorite on the front of the specimen average one centimetre in length, but reach a length of two centimetres or more: they are of the habit shown in fig. 1 in vol. xi, p. 294 of this magazine, with deeply striated prisms and a brachydome. The faces of the brachydome are specially deeply etched, and from the pits and grooves light is reflected from minute faces parallel to the brachypinacoid and a pyramid. These crystals are too large and rough for measurement, but a small bright crystal from a cavity at the back of the specimen was found for this purpose; this crystal, on which the pyramid-planes were largely developed, showed the following forms:—*ab*, *nmlkgu*, *xyy*, *s*, $pq\rho$, δr, $\omega\beta$.

On another noteworthy specimen from Oruro, the several large crystals of andorite measure $2 \times 1{\cdot}5 \times 0{\cdot}5$ cm.; they are flattened prisms (tabular parallel to the macropinacoid) with numerous well-developed terminal planes.

Note on the Systematic Position of Andorite.

In the textbooks andorite has usually been placed in the chalcostibite group, and considered to be an argentiferous zinckenite. This, however, is incorrect, as will be shown below.

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The parameters given by Professor P. von Groth [1] are arrived at as follows:—

Andorite (Brögger),	$a : b : c = 0.6771 : 1 : 0.4458$
Andorite (Groth),	$\frac{1}{2}a : c : \frac{1}{4}b = 0.5696 : 1 : 0.5608$
Chalcostibite,	$a : b : c = 0.5312 : 1 : 0.6395$

Although Groth's parameters for andorite and chalcostibite differ only in the second place of decimals, yet when the corresponding angles are compared it is seen that between one pair there is a difference of nearly 6°.

Andorite, $100 : 803 = 29° 40'$, $010 : 230 = 44° 38'$, $010 : 041 = 29° 17'$.
Chalcostibite, $100 : 110 = 27° 59'$, $001 : 101 = 50° 17'$, $001 : 011 = 32° 36'$.

By placing an orthorhombic crystal in one or other of the six possible positions and selecting a suitable parametral plane, it is possible to obtain an apparent agreement in the parametral ratios of any two orthorhombic minerals. Brögger's comparison of the parameters of andorite ('sundtite') and aeschynite is, indeed, closer than Groth's comparison of andorite and chalcostibite. Groth's parametral plane for andorite would be Brögger's (8.12.3), but this is not developed on the crystals, which are exceptionally rich in pyramidal planes.

Consequent upon the assumption that andorite is an isomorphous member of the chalcostibite group, Groth considers it to be an argentiferous zinckenite with the formula $(Pb, Ag_2)Sb_2S_4$, indicating that lead and silver may replace each other in indefinite proportions. There can be little doubt, however, that andorite is really a double salt with the definite formula $2(PbS.Sb_2S_3).(Ag_2S.Sb_2S_3) = PbAgSb_3S_6$. The four analyses, made independently on material from two localities, all approximate to this formula, as does also an analysis of stannite containing 8·58 per cent. of admixed andorite [2]. The following are the atomic ratios derived from these four analyses:—

	Pb	:	Ag [3]	:	Sb	:	S.
Loczka, 1892 . . .	0·880	:	0·945	:	2·867	:	6
Mann, 1894	1·004	:	0·900	:	2·896	:	6
Prior, 1897	0·923	:	1·042	:	3·002	:	6
„ „	1·013	:	0·975	:	2·990	:	6

In any discussion of these analytical results the following points must

[1] P. von Groth. 'Tabell. Uebers. d. Mineralien,' 1898, 4th edition, pp. 32–3. The parameters (0·5747 : 1 : 0·5618) actually given by Groth are based on the less accurate measurements of Krenner. Groth incorrectly states that andorite has a perfect cleavage; there is no cleavage.

[2] Min. Mag., 1901, vol. xiii, p. 61.

[3] With silver is included 0·65 to 0·73 per cent. of copper. Copper minerals were not found on any of the specimens used for analysis.

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be borne in mind:—(1) There is no statement of the quantity and quality of the material analysed by Loczka. (2) Mann made three analyses of material from the same specimen, one portion being andorite ('webnerite'), another consisting of needles referred to zinckenite, while the third was a mixture of these two minerals; but it is to be remarked that the third analysis is not intermediate between the two others, so there must be some error. (3) Prior's first analysis was made on only a small amount (0·2078 gram) of material not of ideal quality. (4) His second analysis, made on half a gram of pure crystals, is no doubt the most reliable of all the four analyses, and it is the one which agrees most closely with the formula proposed.

The meta-sulphantimonites of lead and silver crystallize in three distinct forms, viz.:—

1. Zinckenite, the orthorhombic lead salt, $PbSb_2S_4$, sometimes containing a fraction of a per cent. of silver. (In the isomorphous group, including chalcostibite, sartorite, and emplectite, no silver salt is known.)
2. Andorite, the double salt, $PbAgSb_3S_6$, also orthorhombic, but with no other crystallographic relation to zinckenite. (This does not fall into any isomorphous group.)
3. Miargyrite, the monoclinic silver salt, $AgSbS_2$, sometimes containing one or two per cent. of lead. (Lorandite, $TlAsS_2$, is probably isomorphous with this, but no corresponding lead salt is known.)

The relation which exists between these three minerals is exactly the same as in certain well-known cases[1] amongst artificial salts, where we have an isodimorphous (or more correctly a crypto-isodimorphous) pair of simple salts with a double salt. Thus, potassium nitrate and silver nitrate form three kinds of crystals:—

1. Orthorhombic KNO_3, with very little $AgNO_3$.
2. Monoclinic $KAg(NO_3)_2$; a double salt.
3. Orthorhombic $AgNO_3$, with very little KNO_3.

A similar case among minerals is supplied by calcite, barytocalcite ($CaBaC_2O_6$), and witherite.

A series of quite another kind in which andorite may also be placed is, as I have already pointed out[2], the morphotropic series formed by this mineral with the double (silver-lead) salts diaphorite and freiesle-

[1] See, e.g., Professor Miers's 'Mineralogy', 1902, p. 231.

[2] Amer. Journ. Sci., 1898, ser. 4, vol. vi, p. 316.

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benite. These three minerals resemble each other so closely in appearance, that, as a rule, they can only be distinguished by measurement of the crystals. In all there is a prism of very nearly 90°, and taking this prism to be {110} the axial ratios, as usually accepted, become:—

		Chem. comp.	Sp.gr.
Andorite,	$\frac{1}{2}a:b:c = 1{\cdot}0157:1:0{\cdot}4458$	$RS.Sb_2S_3$	5·35
Diaphorite,	$2a:b:c = 0{\cdot}9889:1:0{\cdot}7345$	$2RS.Sb_2S_3$?	6·0
Freieslebenite,	$\frac{1}{2}a:b:c = 0{\cdot}9786:1:0{\cdot}9277$	$2\frac{1}{2}RS.Sb_2S_3$	6·3

In this series, increased basicity is accompanied by an increase in length of the vertical crystallographic axis, the vertical axes being in the ratio of approximately 3 : 5 : 6. This is the same kind of relation as that existing between the minerals humite, chondrodite, and clinohumite, and between plagionite, heteromorphite, and semseyite[1].

4. Chalcostibite from Oruro.

Two specimens of this orthorhombic sulphantimonite of copper ($CuSbS_2$) have recently been described from the Pulacayo mine, Huanchaca, Bolivia[2]. The crystals now to be described are from Oruro, which is a new locality for this rare mineral[3].

One (no. 84687) of the two specimens is that described under augelite (p. 323). The other (no. 84684), from the San José mine at Oruro, has been referred to under stannite[4]. Associated minerals are andorite, stannite, quartz, iron-pyrites, &c. The bright, tabular or blade-shaped crystals of chalcostibite occur in cavities in massive tetrahedrite, and are usually only of small size, rarely reaching 1 cm. in length and breadth. They are of a steel-grey colour, and have a brilliant metallic lustre. Parallel to the direction of the perfect cleavage, *c*(001), they are tabular in form, and in the direction of the macro-axis are

[1] Min. Mag., 1899, vol. xii, p. 66.

[2] S. L. Penfield and A. Frenzel. 'On the identity of chalcostibite (wolfsbergite) and guejarite, and on chalcostibite from Huanchaca, Bolivia.' Amer. Journ. Sci., 1897, ser. 4, vol. iv, p. 27; Zeits. Kryst. Min., 1897, vol. xxviii, p. 598; abstract Min. Mag., 1897, vol. xi, p. 338.

[3] The locality, Machacamarca, Bolivia, given in C. F. Naumann's 'Elem. d. Min.' (14th edit. by F. Zirkel, 1901, p. 451) and in C. Hintze's 'Handb. d. Min.' (1902, vol. i, p. 996), is based on F. von Sandberger's determination of 'guejarite' (Neues Jahrb. Min., 1886, vol. i, p. 89); Sandberger, however, specially states that the mineral was not chalcostibite (with which 'guejarite' has since been proved to be identical). Compare Min. Mag., 1895, vol. xi, p. 23, and p. 314, above.

[4] Min. Mag., 1901, vol. xiii, p. 64.

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deeply striated. Terminal pyramidal planes are not always to be seen, and when present are usually small and irregularly developed. Though somewhat dull they give good images of the goniometer-signal, and, as is usually the case with this mineral, they have high indices.

The following forms were noted on the three crystals measured. The angles observed were in close agreement with those given by Penfield.

No. 1. $c\{001\}$, $d\{101\}$, $g\{201\}$, $q\{863\}$, $p\{6.12.7\}$. The planes p are largely developed, and the crystal closely resembles Penfield's fig. 2 (loc. cit.).

No. 2. $c\{001\}$, $\Delta_2\{108\}$, $d\{101\}$, $g\{201\}$.

No. 3. $c\{001\}$, $d\{101\}$, $g\{201\}$, $t\{021\}$, $s\{065\}$, $q\{863\}$, $\tau\{261\}$; and other small pyramids not determined, one being in the zone $[c\tau]$ and having the indices $\{6.18.1\}$ or $\{7.21.1\}$. Measured to c 86° and 86° 55′. Calculated $c:(7.21.1)=86°\,23\frac{1}{2}'$, $c:(6.18.1)=85°\,47\frac{1}{2}'$.

5. Augelite from Oruro and Tatasi.

Monoclinic crystals of this basic aluminium phosphate ($AlPO_4.Al(OH)_3$), first found in Sweden, have been recently described[1] from two localities in Bolivia, namely from Machacamarca and Tatasi, both in the department Potosi. The present description records the mineral from still another Bolivian locality.

The single specimen (no. 84687) from Oruro on which crystals of augelite have been found has the whole of the free surface, measuring about 28 × 23 cm., covered with crystals of augelite, mispickel, quartz, iron-pyrites, and stannite. There is a little kaolin, and also some minute yellow globules of cervantite (?) encrusting most of the other minerals. It was not possible to determine with certainty the order of formation of these minerals; the quartz, however, clearly belongs to two generations, there being small crystals on the matrix, and very much smaller crystals encrusting most of the other minerals. The matrix of the specimen consists of massive quartz, iron-pyrites, and tetrahedrite. Cavities at the back of the specimen contain crystals of chalcostibite, andorite, and stannite.

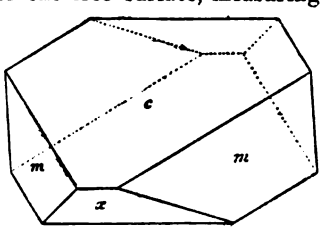

Fig. 3.—Augelite from Oruro, Bolivia.

[1] Min. Mag., 1895, vol. xi, p. 16; 1898, vol. xii, p. 1.

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In themselves the crystals of augelite do not differ from those previously described, but the associated minerals are not the same. The well-developed crystals are 2–4 mm. across and are present in large numbers, so that this is by far the best specimen of augelite that has yet been found. The crystals are colourless and transparent, but usually appear to be yellow and opaque, owing to the surface incrustation of cervantite (?). In habit they are tabular parallel to the basal plane $c\{001\}$; the forms $m\{110\}$ and $x\{\bar{1}01\}$ are also largely developed (fig. 3). Five crystals were measured on the goniometer, but the only other forms observed were $n\{112\}$ and $o\{\bar{1}12\}$, which are rarely present as narrow faces.

Subsequent to the publication in this magazine of the two previous descriptions of crystallized augelite from Bolivia, other specimens from Tatasi have been sent to the Museum by Mr. Roberts. On one of these specimens (Brit. Mus. no. 86723) the crystals of augelite differ from those hitherto described in having a long-prismatic development. A prismatic habit of augelite has already been mentioned, but in the crystals now referred to it is still more pronounced, and might almost be described as acicular. The prism-faces $m\{110\}$ are irregular, owing to parallel growths, and there are no distinct terminal faces. These crystals are colourless and transparent. They occur, together with pale yellow crystals (*mre*) of chalybite and small octahedra of iron-pyrites, in the cavities of a white volcanic rock (altered dacite), which is sprinkled through with iron-pyrites. Coating the other minerals in the cavities is a white, minutely crystalline mineral with a botryoidal surface; it has a specific gravity of 2·84 and was determined to be *pyrophyllite*.

6. New crystal-forms on Vivianite.

The two specimens here described were presented to the British Museum by Mr. M. Roberts; one is from Tatasi and the other from Tasna. The crystals on both have the form of a rectangular prism bounded by $b\{010\}$ and $a\{100\}$, and somewhat flattened parallel to $b\{011\}$: the predominating terminal planes belong to the form $v\{\bar{1}11\}$, and are deeply striated parallel to their intersections with $b\{010\}$. The other faces are bright and smooth, but sometimes, owing to the softness of the crystals, they have been bent by crushing. The colour of the crystals is indigo-blue by reflected light, and sea-green by transmitted light. In each case the associated minerals are chalybite and iron-pyrites, together with some other minerals on one of the specimens.

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On the specimen (no. 86726) from Tatasi, two or three vivianite crystals, 1·5 cm. in length, rest on a matrix of massive chalybite, which has a botryoidal surface and is sprinkled throughout with minute crystals of iron-pyrites. The forms[1] determined on one crystal were *b* {010}, *a* {100}, *y* {310}, *m* {110}, *h* {250}, *z* {112}, *w* {$\bar{1}$01}, *v* {$\bar{1}$11} and *s* {$\bar{1}$31}. The new form *h* {250} is present on three edges as narrow, vertically-striated faces, which gave $ah = 61\frac{3}{4}°$ (calculated 61° 9′).

The specimen (no. 1905, 101) from Tasna (Eugenia vein, Gabriela gallery) consists of a matrix of brecciated tourmaline-rock cemented with chalybite, which shows large cleavage-surfaces. Associated minerals are needles of white tourmaline, bright cubo-octahedra (with small *e* {210}) of iron-pyrites, small crystals of chalybite in acute rhombohedra with or without prism-faces *a* {10$\bar{1}$}, and a few small crystals of quartz and apatite (see below, p. 338). The largest crystal of vivianite measures 2 cm. in length and 1 cm. across.

The forms determined on one crystal are *b* {010}, *a* {100}, *y* {310}, *m* {110}, *w* {$\bar{1}$01} and *v* {$\bar{1}$11}. Between *m* and *b* there are narrow planes which are striated vertically and somewhat curved: measurements to *a* gave in one case 66°, and in another 71°, corresponding with {130} and {140} respectively (calculated (100):(130) = 65° 20′, (100):(140) = 71° 0′).

On another crystal the forms are *b* {010}, *a* {100}, *m* {110}, *n* {101}, *x* {111}, *z* {112}, *w* {$\bar{1}$01}, *v* {$\bar{1}$11}, *s* {$\bar{1}$31}, *r* {$\bar{1}$12}. There are also the same narrow, rounded planes between *m* and *b*, giving in this case a band of reflected images at 60°–67° from *a*. In the striated zone [*bvw*] there are two minute planes at 12° from *w*, corresponding to the position of (838) (calculated ($\bar{1}$01):(838)=12° 7′).

7. Tetrahedrite from Pulacayo Mine, Huanchaca.

Crystallized specimens of fahlerz from this locality are well known in mineral collections. Two distinct types of crystals may be distinguished.

In the more common type, the crystals are steel-grey in colour and have a bright metallic-lustre; the habit is tetrahedral; and the associated minerals are drusy quartz, crystals of copper-pyrites, and massive iron-pyrites. The predominating form is the triakistetrahedron *n* {211};

[1] The forms and angles are as given by Dana, 'System of Mineralogy,' 6th edit., 1892. Dana erroneously gives *s* {311} for *s* {$\bar{1}$31}.

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small faces of the rhombic dodecahedron, $d\{110\}$, are also present. The crystals are usually twinned, with interpenetration, about a triad axis; and these twinned crystals are remarkable in not having the full number of faces of the triakistetrahedron developed. In the octant in which the twin-axis emerges they are completely absent, being replaced by a tetrahedron face (the twin-plane) perpendicular to the twin-axis: the elevation in fig. 4 is represented as bounded at its base by the face $1\bar{1}\bar{1}$, perpendicular to the vertical twin-axis. In each of the other three alternate octants only two faces of the triakistetrahedron are developed; the third being absent or only small in size, as represented at 211 in fig. 6 (this face being here parallel to the twin-axis). Usually, also, one

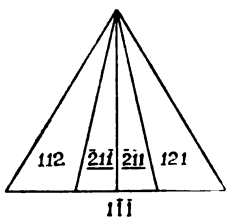

Fig. 4.

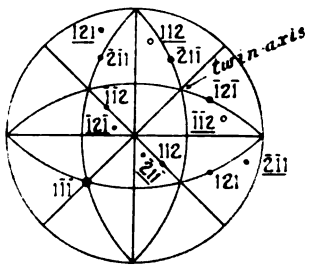

Fig. 7.

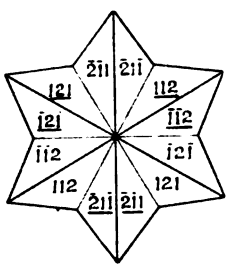

Fig. 5.

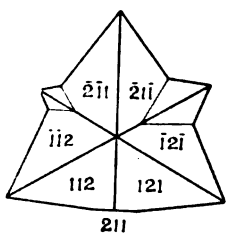

Fig. 6.

FIGS. 4–7.—Tetrahedrite from Pulacayo mine, Bolivia. Plans, elevation, and stereographic projection of twinned triakistetrahedra.

of the interpenetrating crystals predominates in size, and the second crystal is present as disconnected twinned portions projecting as ridges from the main crystal (fig. 6). These projecting ridges may differ in size in the different octants, or may sometimes be altogether absent, their place being then taken by the third triakistetrahedral face of the main crystal (fig. 6).

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The second type of tetrahedrite from the Pulacayo mine is much less frequently met with, and in the British Museum is represented by only one specimen (no. 86480), which came from the Hohmann collection. In appearance and habit the crystals are very like the tennantite ('binnite') from the Binnenthal in Switzerland: they also somewhat resemble crystals of black blende. The colour is iron-black; and the lustre is brilliant and metallic with a velvety appearance. The streak is black. The matrix of the specimen is a decomposed volcanic rock impregnated with iron-pyrites and kaolin. A chemical examination showed the presence of much copper, antimony, and sulphur, some silver and iron, but no arsenic: the crystals are therefore tetrahedrite, and not tennantite. The larger crystals, measuring up to 1 cm. across, are not twinned, and have only the forms $d\{110\}$ and $n\{211\}$, which are approximately equally developed. The smaller crystals are twinned, with interpenetration, about a triad axis. In addition to the forms $d\{110\}$ and $n\{211\}$, these crystals have faces in the zones [111, 110], namely, $\Delta\{774\}$, $p\{221\}$, and $\Sigma\{552\}$. These faces are somewhat uneven and oscillatory in character, and all lie with $n\{211\}$ in the same (positive) octants, the twin-plane (I11) being in an adjacent (negative) octant. Measurements in this oscillatory zone gave:

	Measured.	Calculated.
$d\Sigma = 110:552$	15° 46′	15° 48′
$n\Sigma = 112:552$	$37\frac{3}{4}°$–$38\frac{3}{4}°$	38 $56\frac{1}{2}$
$d\Delta = 110:774$	$22\frac{1}{2}°$–$24\frac{1}{2}°$	22 0
$dp = 110:221$	19° 15′	19 $28\frac{1}{2}$

The form $\Delta\{774\}$ has already been observed on fahlerz from the Pulacayo mine by G. vom Rath[1]; and $\Sigma\{552\}$ has been recorded for the Binnenthal tennantite.

8. Regular grouping of Stannite and Tetrahedrite.

A specimen (Brit. Mus. no. 86471), acquired from the collection of the late T. Hohmann, and coming from the Socavon de la Virgen at Oruro, consists of a group of bright crystals of tetrahedrite on a matrix of massive iron-pyrites. The tetrahedrite crystals are tetrahedral in habit and have the forms $n\{211\}$, $o\{111\}$, and $d\{110\}$, the first predominating, as shown in the accompanying figure: the crystals measure 1·5 cm. along the tetrahedral edge. On the free surface of the specimen are crystals (*oae*) of iron-pyrites, and encrusting all the other minerals are small crystals of quartz.

[1] Sitzungsber. niederrhein. Ges., Bonn, 1886, Jahrg. xliii, p. 190.

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The stannite crystals are plentifully scattered over the tetrahedrite, in the surface of which they are partly embedded; they are quite small ($\frac{1}{4}$–$\frac{1}{2}$ mm. across), and of the same appearance and pseudo-cubic habit as the crystals of stannite previously described from Oruro[1]. The stannite is iron-black with a sub-adamantine lustre, while the tetrahedrite is steel-grey with metallic lustre.

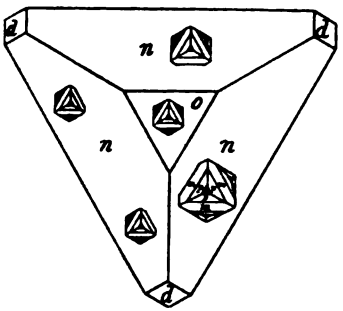

Fig. 8.—Composite pseudo-cubic crystals of stannite in parallel growth on tetrahedrite from Oruro.

The orientation of the pseudo-cubic crystals is parallel to that of the cubic crystals. The three sphenoidal planes, p(111), which in a composite crystal of stannite form a face of the pseudo-tetrahedron, reflect light with a tetrahedron face of the tetrahedrite; and the prism faces, m(110), of the former are parallel (or very nearly parallel) to the rhombic-dodecahedral faces of the latter.

9. Axial ratios and analysis of Valentinite.

Crystals of valentinite are present on four specimens from Tatasi (from the Tusti and Aranzasu veins) presented to the British Museum by Mr. M. Roberts in 1897 and 1899. The crystals are usually flattened parallel to $b\{010\}$, and are arranged in fan-shaped groups with the vertical (c) axes of the different crystals coincident. The largest group of crystals measures 1 cm. across. On one specimen, however, the crystals are not grouped together, but are scattered singly over the surface of the matrix, and they are not tabular in habit. The crystals are associated[2] with octahedra of iron-pyrites on a matrix of a compact, fibrous sulphantimonite of lead with massive iron-pyrites.

The optical characters of the crystals conform with orthorhombic symmetry. The extinction is straight on b(010), m(110), and a(100). The acute, negative bisectrix is perpendicular to a(100); and for red (Li) and yellow (Na) light the plane of the optic axes is parallel to c(001), whilst

[1] Min. Mag., 1901, vol. xiii, p. 54.

[2] On one specimen there are small crystals of chalybite, pyrargyrite, and pyrostilpnite. The *pyrostilpnite* has the form of thin blades, which, between crossed nicols, extinguish at 11° to their long edges. Goniometric measurements led to no definite results. On other specimens from Tatasi, blades of pyrostilpnite are associated with crystals of tetrahedrite.

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for green (Tl) light it is parallel to $b(010)$; the axial angles are small. The refractive index was determined by Dr. G. F. Herbert Smith through prisms bounded by mm and by bm; the mean of several determinations with sodium light was 2·84. The dispersion is high, and a prism gives a long spectrum with white light.

Owing to the approximate parallel grouping of the crystals, the faces are much intergrown and are very uneven; and, owing to the softness and perfect cleavages of the crystals, they become distorted at the slightest touch. Further, the vicinal character of the faces in the brachydome zone presents difficulties in the measurement of the crystals. On many of the crystals, however, there are small, smooth, and bright faces of a pyramid, which in being developed on the free corners are less liable to distortion than the other faces.

By carefully detaching crystals, still attached to a fragment of the matrix, from a cavity of one of the specimens, the crystals were measured without being touched, and thus without danger of distortion. In this way some excellent readings were obtained from the pyramid-faces. These faces gave single, sharp images, which could often be observed with the eye-piece of the highest magnification of the Fuess no. 2 goniometer. The means of several readings on the three best crystals are:—

$$oo' = 32° 31\tfrac{3}{4}' \text{ (limits } 32° 29\tfrac{1}{2}' - 32° 34').$$
$$om = 40\ \ 9\ \ (\ ,,\ \ 40\ \ 5\ \ -40\ \ 11\tfrac{1}{2}).$$

This pyramid is new for valentinite, and referred to the axes of Groth and Laspeyres has the indices $\{554\}$. Taking it, however, to be the unit pyramid $\{111\}$, the angles given above correspond with the axial ratios:—

$$a : b : c = 0·3938 : 1 : 0·4344.$$

Eleven crystals were measured on the goniometer, and the following forms determined:—

$a\ \{100\}$, a narrow face.
$b\ \{010\}$, large, giving scattered images.
$c\ \{001\}$, a narrow face; rarely present.
$m\ \{110\}$, often curved, owing to the fan-shaped grouping of the crystals and to the fibrous m cleavage.
$o\ \{111\}$, small, smooth, and bright faces.
$i\ \{011\}$, narrow
$e\ \{072\}$,
$r\ \{031\}$, narrow
$s\ \{041\}$,
} These are vicinal faces lying near the positions given by the indices.

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The vicinal faces in the brachydome zone are bright and smooth or striated parallel to their mutual intersections. There are usually two large and well-defined faces near the positions of *e* and *s*, which are sometimes equal in width, but often *e* is the larger. The angles (*es*) between them were measured on different crystals as: 1° 37′, 1° 45′, 8° 6′, 3° 18′, 3° 34′, 3° 40′ and 4° 5′ (two images), 3° 47′ and 4° 6′ (two images), 3° 49′ and 4° 1′ (two images), 5° 53′.

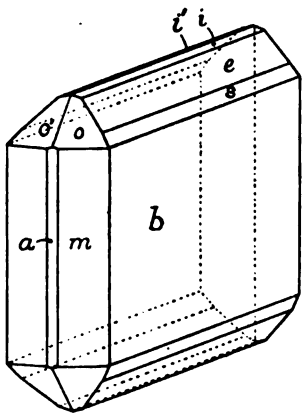

Fig. 9. — Valentinite from Tatasi, Bolivia. (The planes at the further, attached end of the crystal represent the prismatic cleavage.)

While measuring the crystals, difficulty was often experienced in separating the scattered images, and in the following table only the better angles are given. The calculated angles are deduced from the axial ratios given above.

	Calculated.	Measured.		Limits.	No.
$ii' = (011):(0\bar{1}1)$	46° 57½′	46° 58′	46° 47′	— 47° 2′	3
$ee' = (072):(0\bar{7}2)$	113 20	112 56	112 39	— 113 20	4
$eb = (072):(010)$	33 20	33 4	32 21	— 34 23	9
$rb = (031):(010)$	37 30	37 3	36 19,	37 48	2
$ss' = (041):(0\bar{4}1)$	120 9	119 42			1
$sb = (041):(010)$	29 55½	29 43	28 44	— 30 39	9
$oi = (111):(011)$	45 20	45 10½	45 3½	— 45 15	4
$oe = (111):(072)$	53 59½	53 43	53 37	— 53 46	6
$os = (111):(041)$	55 38½	55 23	55 12	— 55 34	3
$mm' = (110):(1\bar{1}0)$	42 59	42 20	40½°	— 43½°	6

The measured angles for the vicinal faces thus vary considerably from the calculated values, but far wider variations than those recorded above were observed. The measurements of the prism-angle also varied between wide limits[1].

The axial ratios and complex indices of valentinite have been critically studied by P. von Groth (1869 and 1874), H. Laspeyres (1884), and A. Brezina (1886); but since previous calculations are based on measurements made in the brachydome- and prism-zones, the problem

[1] Values previously given for the prism (cleavage) angle are: 42° 17′ (W. Phillips, 1823), 43° 2′ (F. Mohs, 1824), 42° 18′ (P. von Groth, 1869), 41° 50′ (P. von Groth, 1874), 42° 41′ (H. Laspeyres, 1884).

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has been complicated by deducing axial ratios after high indices have been assigned to the faces, which are really only vicinal in character. The parametral plane selected above, and now, for the first time, observed as an actual crystal-face, was chosen by Brezina[1] in the more likely of his two interpretations of the crystals; and, from Laspeyres's measurements, he deduced the axial ratios $a:b:c = 0{\cdot}3915:1:0{\cdot}4205$, corresponding with those given above.

These axial ratios have, however, the disadvantage of failing to indicate the isomorphism of valentinite with the monoclinic claudetite (As_2O_3). But since no analysis[2] has been made of the former mineral, there is no direct evidence that the formula is Sb_2O_3. It was, therefore, thought advisable to analyse the Bolivian crystals. For this purpose 0·5498 gram of pure crystallized material was collected by Dr. G. F. Herbert Smith and analysed by Dr. G. T. Prior, with the following results, which agree with the accepted formula Sb_2O_3:—

		Atomic ratios.	
Sb	82·79	0·693	2
O (by difference)[3]	17·21	1·084	3
As	trace[4]		
	100·00		
Specific gravity[5]	5·76		

Most of the observations recorded above were made in 1897, and although not altogether satisfactory, they may be of some value beyond recording a new locality for the mineral. The crystals were also measured by Dr. G. F. Herbert Smith, but with no further results, and he also found them to be unsuitable for accurate determinations of the optical constants.

[1] Ann. k.k. naturhist. Hofmus. Wien, 1886, vol. i, p. 145.

[2] An analysis of acicular crystals of 'white antimony' from Pereta in Tuscany gave E. Bechi (Amer. Journ. Sci., 1852, ser. 2, vol. xiv, p. 60) Sb, 78·83; O, 19·47; Fe, 1·25; gangue, 0·75 = 100·30. This suggests the formula Sb_2O_4, and is quoted by Dana ('System of Mineralogy,' 5th edit., 1868, p. 187) under cervantite.

[3] An attempt to determine the oxygen directly, by heating the mineral in a current of hydrogen and weighing the water so formed, was unsuccessful, owing to the ready fusibility of the reduced metal.

[4] Detected by the Babo-Fresenius test.

[5] The value, 5·566, usually quoted for the specific gravity of valentinite, is due to W. Haidinger (Edinburgh Journ. Sci., 1825, vol. ii, p. 73; and quoted earlier in F. Mohs's 'Grund-Riss d. Mineralogie,' 1824).

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10. Cassiterite.

Specimens of cassiterite collected by Sir Martin Conway from the mountain of Huaina Potosi, near La Paz, are compact to fine-grained in texture, and light to dark brown in colour; they are often iron-stained. Except for the heaviness (specific gravity) of the specimens there would be nothing to suggest on a casual examination that the material is cassiterite. Cavities are lined with minute, very indistinct crystals of cassiterite, which are light to dark brown, and translucent to opaque. Quartz, iron-pyrites, and sometimes bismuthinite (Bi_2S_3) are present in small amounts, mixed with the massive cassiterite. In one specimen the grains of cassiterite are embedded in a dirty green chloritic substance. A thin section of this specimen shows, under the microscope, an iron-stained aggregate of cassiterite, chlorite, and quartz: the cassiterite grains are frequently twinned.

The most coarsely crystallized specimen (Brit. Mus. no. 84694 A), from the Chacaltaya mine, on Huaina Potosi, shows in the cavities dark crystals of cassiterite 1–2 mm. across. These crystals interpenetrate each other and are difficult to decipher; the faces are very uneven and curved. What appear to be hexagonal pyramids can sometimes be distinguished. Measurements show that these are really groups of six crystals twinned together in such a manner that the principal crystallographic axes and the twin-axes of all the individuals lie in the same plane. The form present is the deeply striated prism $m\{110\}$, with very narrow planes of $a\{100\}$ on a few of the edges. In fig. 10 the six individuals are marked $m_1 \ldots m_6$; of these, m_1 is placed in the normal position with the prism-edge and the striations vertical. The second and sixth crystals are twinned on (101) and (10$\bar{1}$) respectively of the first crystal; the fifth and sixth are in twin position with respect to the fourth and first respectively, but not with respect to each other. This type of repeated twinning with the twin-axes all in the same plane is frequent in rutile, but rare in cassiterite [1].

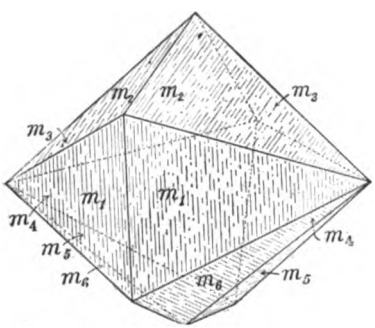

Fig. 10.—Cassiterite from Huaina Potosi, Bolivia.

Six crystals twinned together, producing a pseudo-hexagonal bipyramid.

[1] W. Phillips, Trans. Geol. Soc. London, 1814, vol. ii, p. 378, plate 25, figs. 208–15. W. Haidinger, Edinburgh Journ. Sci., 1825, vol. iii, p. 61, plate 8, fig. 7.

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Sir Martin Conway's collection also includes specimens from Oruro of much the same character: they are heavy, pale brown, somewhat porous masses, with minute and indistinct crystals of cassiterite lining the cavities. In the cavities of one specimen are pentagonal dodecahedra $e\{210\}$ of iron-pyrites, and in another the cavities are lined with small quartz crystals. Massive iron-pyrites and a black mineral with metallic lustre occur in small quantities intermixed with the massive cassiterite. A thin section of a specimen from the San José mine shows, under the microscope, a porous aggregate of small, interlocking, pale yellow crystals of cassiterite. The index of refraction and the double refraction are high. Twinning is frequent, and sometimes often repeated; the line of junction between the individuals of a twin is always sharp and straight.

Compactness is a characteristic feature of Bolivian tin-ores. Crystals of cassiterite, other than those of minute size, are only exceptionally met with: in the British Museum collection there are only four isolated crystals of any appreciable size. They are simple (i. e. not twinned) crystals of prismatic habit. One of them (Brit. Mus. no. 86822) measures $20 \times 5 \times 5$ mm., and was sent by Mr. M. Roberts from Tasna; it has the forms $m\{110\}$ and $s\{111\}$. Two crystals (Brit. Mus. no. 87070) from Tres Cruces (=Quimza Cruz) in the province Inquisivi, department La Paz, were presented by Mr. John B. Minchin in 1904. The larger of these measures $21 \times 11 \times 11$ mm., and has the forms $m\{110\}$, $e\{101\}$, $s\{111\}$, $z\{321\}$, and $t\{313\}$; the prism faces are roughly striated and uneven, being replaced by oscillatory vicinal faces $\{970\}$, $\rho\{750\}$, &c. The rather smaller crystal, on which the same forms are present, is translucent and shows zonal bands of colour (brown, yellow, and almost colourless) parallel to the z planes: it is distinctly pleochroic, the absorption being greater for vibrations parallel to the vertical (c) axis, although the tone of the colours remains the same. Both Mr. Minchin and Dr. Richard Pearce have informed me that good, crystallized specimens of cassiterite, with larger crystals than those here described, are by no means uncommon at Tres Cruces.

11. Tourmaline and Tourmaline-Hornfels from Tasna.

Tourmaline of quite an unusual habit and appearance was unexpectedly found on several specimens sent by Mr. M. Roberts in 1905 from the tin and bismuth mines at Tasna, province of Nor-Chichas, department of Potosi. The mineral has the form of very fine, colourless or pale greyish-green needles, but owing to differences in the state of aggrega-

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tion it varies considerably in appearance. The associated minerals are cassiterite, wolframite, mispickel, iron-pyrites, marcasite, quartz, vivianite. chalybite, apatite, and native sulphur, but these are not all present together on the same hand-specimen.

The needles, taken from different specimens, have a maximum length of 1 to 2 mm. and a thickness of 0·01 to 0·05 mm. Under the microscope, in ordinary light, they are seen to be very faintly tinged with green: sometimes the needles are slightly lighter in colour at their flat pyramidal terminations. The pleochroism is feeble, yet distinct: for vibrations parallel to the length of the needles the transmitted light is colourless, and for vibrations perpendicular thereto it is faint yellowish-green or sometimes bluish-green. The needles extinguish parallel to their length, and are optically negative. The specific gravity is 3·0. Chemical tests proved the presence of boron.

On one specimen the tourmaline forms the matrix of crystals of wolframite and mispickel[1], and has, at first sight, the appearance of a pale greenish-grey vesicular lava. This consists of a more or less compact, matted aggregate of the fine tourmaline needles, which are best seen in the round cavities, where they are more loosely aggregated. On another specimen the tourmaline needles are shorter and smaller and form a more or less compact, yellowish or dark-grey rock, somewhat resembling a sandy shale in appearance: this tourmaline-rock has been brecciated and the fragments cemented together with chalybite, on which is a later growth of tourmaline needles. On a third specimen, a few rather larger, colourless needles are confusedly grouped with quartz crystals and brilliant tin-white crystals of mispickel (forms *m* and *e*) in a cavity in massive mispickel and iron-pyrites. On a fourth, the tourmaline has the form of very fine, colourless or white, silky hairs growing out from a matrix of tourmaline-hornfels impregnated with small, indistinct crystals of cassiterite. On a fifth specimen, the bluish-greenish needles form small divergent tufts, with a velvety appearance, on the mamillated surface of brown, compact cassiterite with massive iron-pyrites. Only

[1] The *wolframite* crystals have a brilliant lustre and are tabular parallel to $t\{102\}$; the following forms were determined by the goniometrical measurement of one crystal:—$a\{100\}$, $b\{010\}$, $c\{001\}$, $t\{102\}$, $m\{110\}$, $l\{210\}$, $f\{011\}$, $\omega\{111\}$, $\sigma\{121\}$.

The *mispickel* (arsenopyrite) crystals are bright with a purplish tarnish: in habit they are exactly like fig. 2 in Dana's 'System of Mineralogy' (6th edit., 1892, p. 98), though in addition to the forms $e\{101\}$ and $m\{110\}$, which are equally developed, there are very narrow faces of $c\{001\}$.

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on this last specimen is there any attempt at radial grouping of the needles; more usually they are confusedly aggregated or matted.

This colourless, acicular tourmaline is not unlike the achroite or white schorl sometimes met with in the Cornish tin mines. Such material has been described by Mr. J. H. Collins[1] from St. Austell, and in the British Museum collection there are specimens from St. Austell and St. Just.

The matrix of several of the specimens sent by Mr. Roberts from Tasna consists of a very compact, hard rock resembling in appearance a hornstone or a very fine-grained quartzite. This rock I have determined to be a *tourmaline-hornfels*. It occurs in the mineral-veins, and, on different hand-specimens, is associated with cassiterite, wolframite, native bismuth, bismuthinite (Bi_2S_3), iron-pyrites, mispickel, quartz, and tourmaline. It also appears to be of common occurrence amongst the rocks of the Cerro de Tasna, for in a collection of eighteen representative rock-specimens[2] sent by Mr. Roberts half of them are tourmaline-hornfels. One specimen, from the summit of the mountain (5,213 metres above sea-level), is a brecciated tourmaline-hornfels, with the fragments set in a matrix of silvery white scales of *pyrophyllite*[3].

These rocks are usually pale buff- or cream-coloured or greyish; sometimes they show darker bands or are spotted like a spilosite. They have a specific gravity of 2·8 and a hardness of about 7. Thin sections under the microscope show a microcrystalline aggregate of two minerals, one with the birefringence of quartz, and the other with a higher birefringence. The latter is very pale yellowish-green in colour and is not noticeably pleochroic: it predominates in the darker coloured bands and spots of the rock. The suggestion that this mineral might be tourmaline, and the rock a tourmaline-quartz-rock, was given by noticing in a small cavity of one of the specimens some small colourless needles of the same character as those described above, which were identified as tourmaline. A mixture of quartz and tourmaline in about equal proportions would have a specific gravity of 2·8. The rocks were tested for boron, and in each case gave a good flame-colour reaction.

Mr. M. Roberts, who has been actively engaged in mining in Bolivia since 1893 and at Tasna since 1903, writes (November, 1906) to me respecting the rocks of the Cerro de Tasna—'Within 400 metres from the summit there is certainly more tourmaline-hornfels than any other rock. Round the base are the shales, and in these I know of three

[1] Min. Mag., 1876, vol. i, p. 55.

[2] These include altered dacite, clay-slate, quartz-grit, and quartzite.

[3] Another Bolivian occurrence of pyrophyllite is noted above (p. 324).

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dacite-dykes, which are 5 to 15 metres in width: there is no boss of dacite. . . . Personally I have never seen granite[1] in Bolivia and I feel sure that there is none anywhere in the neighbourhood of Tasna.' In a previous letter he remarked that the hard, compact 'quartzites' (i. e. tourmaline-hornfels) present a difficulty in the exploitation of the tin-veins.

There thus seems to be an abundance of tourmaline associated with the tin and bismuth ores of Tasna, and the reason why it has been previously overlooked can only be ascribed to the peculiar form which the mineral takes. The frequent occurrence of a hard, compact hornfels was mentioned by the late Professor A. W. Stelzner[2]; and he considered it to be a silicified product of the clay-slates, formed either in connexion with the mineral-veins or by metamorphic action of the dacite-dykes.

The supposed absence of tourmaline in the tin-veins of Bolivia has been especially emphasized by Stelzner[3], and hitherto only a few isolated occurrences have been recorded. In his earlier Bolivian paper[4], Stelzner mentions in a footnote the occurrence of tourmaline in the tin-veins of Chorolque; but in his later, posthumous paper[5] it is only mentioned by the editor in an appendix, the authority being Stelzner's labels with two specimens in the Freiberg collection.

D. Forbes[6] mentions it as occurring in the Baldomero mine on Mount Illampu, near Sorato, together with gold, bismuth, tetradymite, apatite, &c. Prof. T. G. Bonney[7] also notes the presence of tourmaline, in radiating groups of black acicular crystals with quartz and felspar, amongst the rock-specimens (granite, &c.) collected by Sir Martin Conway on Mount Sorata (= Illampu).

Dr. R. Pöhlmann[8] in his description of the Hohmann collection mentions eight specimens of tourmaline from Chilian and Bolivian ore-deposits. Dr. G. F. Kunz[9], in his annual report on precious stones for

[1] Specimens of granite were collected by Sir Martin Conway high up on Mt. Sorata (see 'Bolivian Andes', p. 373).

[2] A. W. Stelzner. 'Die Silber-Zinnerzlagerstätten Bolivias. Ein Beitrag zur Naturgeschichte des Zinnerzes.' Zeits. Deutsch. geol. Ges., 1897, vol. xlix, pp. 51–142 (see pp. 135–6).

[3] Loc. cit., p. 116.

[4] Zeits. Deutsch. geol. Ges., 1892, vol. xliv, p. 532 (footnote).

[5] Ibid., 1897, vol. xlix, p. 137.

[6] Phil. Mag., 1865, ser. 4, vol. xxix, p. 2.

[7] Sir M. Conway, 'The Bolivian Andes,' 1901, p. 372.

[8] Verh. Deutsch. wiss. Ver. Santiago de Chile, 1899, vol. iv, p. 83. Most of these specimens are probably from Chilian copper-lodes.

[9] Mineral Resources of the United States, for 1903, 1904, p. 966 (p. 60 of reprint).

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1903, quotes, on the authority of Dr. G. F. Bandelier, 'Tourmaline.—The common black variety accompanying cassiterite occurs near La Paz.' Lastly, Dr. Richard Pearce[1] mentions the occurrence of delicate, greenish needles of tourmaline with tin-ore in the Tres Cruces district; and he has informed me that it is there rather abundant.

12. Fluorite.

In a cavity of the more coarsely crystallized specimen (Brit. Mus. no. 84694 A) of cassiterite from the Chacaltaya mine, Huaina Potosi, mentioned above, there is a group, about 1 cm. across, of corroded crystals of white fluorite, associated with quartz and limonite. The crystals appear to be octahedra, and were found to possess the physical, optical, and chemical characters of fluorite. The refractive index was determined, through a prism bounded by the cleavages, to be about 1·44.

This occurrence is of interest, since fluorite is of extremely rare occurrence in Bolivia. Both Arzruni[2] and Stelzner[3] have remarked on its absence from the tin-stone veins of this region. Curiously enough, however, worked beads of pale-yellow and rose-red fluorite have been found by A. Stübel[4] in the ancient ruins of Tiahuanaco on Lake Titicaca. It has been suggested that this material was brought by the Incas from some locality now in Peru.

D. Forbes[5] in 1861 gives fluor-spar in his list of minerals occurring in the mineral-veins of Bolivia, but he gives no precise locality or other details. I. Domeyko[6] in 1879 recorded its occurrence with the copper ores (not tin) in the Cretaceous strata at Corocoro near La Paz, and recently[7], transparent, green fluorite from this locality has been mistaken for emerald.

C. S. Pasley[8] states that fluorite is found with iron-pyrites and tin-

[1] Trans. R. Geol. Soc. Cornwall, 1906, vol. xiii, p. 105. It is here stated that Mr. D. A. MacAlister has detected tourmaline in a specimen of Bolivian tin-ore.

[2] Zeits. Kryst. Min., 1884, vol. ix, p. 75.

[3] Zeits. Deutsch. geol. Ges., 1897, vol. xlix, p. 116.

[4] Zeits. Kryst. Min., 1880, vol. iv, p. 370; 1881, vol. v, p. 580.

[5] Quart. Journ. Geol. Soc., 1861, vol. xvii, p. 60.

[6] I. Domeyko, 'Mineralojia,' 3rd edit., Santiago de Chile, 1879, p. 717.

[7] G. F. Kunz, Mineral Resources of the United States, for 1903, 1904, p. 968 (p. 62 of the reprint of Kunz's annual report on precious stones, for 1903). W. J. Humphreys (Astrophysical Journ., Chicago, 1904, vol. xx, p. 269) has found yttrium and ytterbium to be present in this fluorite.

[8] C. S. Pasley, 'The tin mines of Bolivia.' Trans. Inst. Mining and Metallurgy, London, 1899, vol. vii, pp. 77-90. Fluorite is mentioned on p. 83.

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stone at Colquiri in the province of Inquisivi, fifty miles north of Oruro. A series of Bolivian tin-ores and mineral specimens was presented by Mr. Pasley in 1898 to the Museum of Practical Geology, London, and amongst them is a specimen of green and purple fluorite from Colquiri, the determination of which as fluorite Dr. W. Pollard has been kind enough to confirm for me. Another mention of Bolivian fluorite is to be found in the Annual Report[1] for 1900–1 of the Museum Senckenbergianum at Frankfurt-am-Main: it is contained in a list of Chilian and Bolivian minerals collected by A. Gmehling, and reads 'Fluorit vom Gang Lipez (Bolivia)'.

18. Apatite.

On the specimen of vivianite from Tasna (Eugenia vein, Gabriela gallery), described above (p. 325), there are a few minute crystals of apatite. One rests directly on a crystal of vivianite, and another, with needles of white tourmaline, is attached to a small crystal of chalybite, which rests on the same crystal of vivianite. The apatite crystals are colourless and transparent, and are beautifully perfect. They are prismatic in habit, and have a length of about 1 mm. The predominating forms are the hexagonal prism, $m\{10\bar{1}0\}$, and the basal pinacoid, $c\{0001\}$. Other forms, present as small, but distinct faces, are the prism $a\{11\bar{2}0\}$ and the pyramids $x\{10\bar{1}1\}$, $y\{20\bar{2}1\}$, and $s\{11\bar{2}1\}$. The measured angles agree closely with the values given by Dana; for example, $my = 30° 30'$ (calculated, 30° 31'). A rough determination of the refractive index, by refraction through the natural prism, gave 1·64. The amount of material was too small for a determination of the specific gravity and for any chemical tests to be made. The refractive index is, however, sufficient to prove that the crystals are apatite, and not pyromorphite or mimetite.

Mention may also be made here of a fine crystal of apatite 'from Bolivia', which was presented to the British Museum in 1903 by Miss Louie Hicks, and was from the collection of her late father, Mr. George Hicks. The meteorites and mineral specimens presented to the British Museum by Mr. Hicks in 1879 were all from the Desert of Atacama, at that time in Bolivian territory, but now in Chili, and it is possible that the apatite crystal may have come from the same region; at any rate, there is nothing to connect the specimen in question with the tin deposits of the Bolivian plateau to the east of the Andes.

[1] Ber. Senckenb. Naturf. Ges., 1901, I Theil, p. 53.

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This specimen (Brit. Mus. no. 86618) is an isolated, stout-prismatic crystal, broken at one end, and without any attached matrix. It measures $4\frac{1}{2}$ cm. in length by 3 cm. in diameter. It is translucent and of a fine oil-green colour; but on the prism-planes there is a thin shell or skin of white, opaque material (apatite). The forms c {0001}, x {10$\bar{1}$1}, a {11$\bar{2}$0}, and m {10$\bar{1}$0} are all prominently developed; the prism-faces a are wider than m, so that the pyramid-faces x are set on the corners of the former prism.

Apatite, like fluorite, tourmaline, and topaz, has been considered to be absent from the Bolivian tin-veins; and, indeed, these minerals have been only occasionally recorded from this region. This may, perhaps, be accounted for by their inconspicuousness and unusual modes of occurrence. A. W. Stelzner in his earlier Bolivian paper mentions[1] the occurrence of apatite, as a rarity, in the tin-veins of Tasna; but in his later, posthumous paper it is only given[2] by the editor in an appendix, the authority being Stelzner's label 'Apatit auf Zinnerz von Tasna' belonging to a specimen in the Freiberg collection. Other statements of the occurrence of apatite in Bolivia are the following. According to D. Forbes[3] it is found in the San Baldomero mine on Mount Illampu, near Sorata, together with gold, bismuth, tetradymite, tourmaline, &c. I. Domeyko[4] mentions large crystals of fluor-apatite from the silver mines at Aullagas, near Colquechaca.

In addition to these occurrences, certain pseudomorphous impressions in compact cassiterite have been suggested to be after apatite. Domeyko[5] mentions a specimen of tin-ore from Bolivia (Oruro or Guanuni) with impressions of hexagonal prisms terminated by obtuse rhombohedra. And Stelzner[6] mentions tin-ore from Tasna with impressions of hexagonal prisms with basal planes.

14. Cupriferous Miargyrite from Tatasi.

A specimen (Brit. Mus. no. 84307), consisting mainly of massive miargyrite with some massive iron-pyrites, was presented to the Museum

[1] Zeits. Deutsch. geol. Ges., 1892, vol. xliv, p. 532 (footnote).

[2] Ibid., 1897, vol. xlix, p. 137.

[3] Phil. Mag., 1865, ser. 4, vol. xxix, p. 2.

[4] I. Domeyko, 'Mineralojia,' 3rd edit., 1879, p. 498. The statement was first made in 1867 in the 2nd appendix to the 2nd edition (Anales de la Universidad de Chile, 1867, vol. xxix, p. 76).

[5] Bull. Soc. Min. France, 1882, vol. v, p. 299. The rhombohedral terminations do not suggest apatite.

[6] Loc. cit., 1897, pp. 137, 138.

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by Mr. M. Roberts in 1897. It is from the Consuelo lode at Tatasi, in the department of Potosi. In cavities there are small spindle-shaped crystals of pale yellow chalybite, some radiating groups of quartz crystals, a few small octahedra of iron-pyrites, and a powdery coating of cervantite (?). Other cavities, in which these minerals are absent, are lined with bright crystal-faces of miargyrite, but only small fragments of crystals could be detached for goniometric measurement, which gave uncertain results.

The massive miargyrite is black and opaque, and has a bright metallic lustre. Thin flakes, when examined under the microscope in bright sunlight, transmit a deep crimson colour. The streak is dark purple to reddish-brown. The fracture of the mineral is uneven to sub-conchoidal, with traces of cleavage. The specific gravity is 5·20, and the hardness $2\frac{1}{2}$. A qualitative chemical analysis showed the presence of sulphur, antimony, silver, copper, iron, and a trace of arsenic.

These characters point either to miargyrite or to a richly argentiferous tetrahedrite, and to distinguish between these it became necessary to make a quantitative analysis. I obtained the following results, which agree with the miargyrite formula, $AgSbS_2$, with part of the silver replaced by copper (Ag : Cu = 8 : 1). Lead is not present in fragments of pure miargyrite giving a purplish streak, but in an intermixed mineral of similar appearance with a black streak.

		Atomic ratios.	Calculated for $8\,AgSbS_2 + CuSbS_2$.
S ...	21·9	... 0·69	... 22·3
Sb ...	40·5	... 0·34	... 41·9
Ag ...	33·9	... 0·32	... 33·4
Cu ...	2·6[1]	... 0·04	... 2·4
Fe ...	1·0	... 0·02	
Pb ...	0·6		100·0
As ...	trace		
	100·5		

15. Miargyrite from Aullagas.

Mention has already been incidentally made in this magazine[2] of the occurrence of crystallized miargyrite at Aullagas, near Colquechaca in

[1] Two determinations gave 2·69 and 2·63 per cent. of copper. No copper mineral was detected on the specimen.

[2] Min. Mag., 1898, vol. xii, p. 12.

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province Chayanta, department Potosi. The specimen, belonging to the Allan-Greg collection, there described consists of massive brongniardite and miargyrite, with some galena, pyrargyrite, and blende, and situated on the miargyrite are small octahedral crystals of argyrodite. The miargyrite is distinguished from the other minerals by its uneven fracture with traces of cleavage and by its dark cherry-red streak. It was examined chemically, and found to contain silver, antimony, and sulphur. In the cavities of the massive material some inconspicuous crystals of miargyrite were found: the following forms[1] were noted on the four fragmentary crystals measured:—

(i) b {010}, t {111}, s {211}, d {311}, ζ {$\bar{2}15$}, χ {$\bar{2}12$}, σ {$\bar{2}11$}, x {$\bar{1}22$}. A bright crystal, not much striated; b is very small. The prominent zones are $[d\,t\,x\,\sigma]$ and $[s\sigma\,\chi\,\zeta]$.

(ii) c {001}, t {111}, s {211}, h {113}, k {124}, x {$\bar{1}22$}. c is large.

(iii) Like No. 2 with d {311}, but without k.

(iv) a {100}, c {001}, t {111}, s {211}, d {311}, g {313}.

Some of the best measured angles are:

	Calculated.	Measured.
$tt' = 111 : \bar{1}1\bar{1}$	54° 55½′	54° 38′
$ts = 111 : 211$	14 17½	14 21, 14° 10′
$tc = 111 : 001$	69 18	68 50, 68° 54′
$s'\sigma = 21\bar{1} : 211$	32 2½	31 53
$ck = 001 : 124$	54 36	54 12

Similar crystals of miargyrite are also present on a specimen[2], labelled Potosi, which was collected by the Castelnau expedition (1843–7); the associated minerals are exactly the same as on the specimen described above, from Aullagas, department Potosi.

Mention may be made here of a large specimen of massive miargyrite, from the silver mines of the Colquechaca Company at Aullagas, a fragment of which is in the British Museum collection (no. 83989). In cavities in the bright, massive miargyrite are a few wires of native silver and some small crystals of pyrargyrite. The matrix is a brecciated, light-coloured rock, in the interstices of which are lenticular crystals of chalybite, crystals of reddish-brown blende and quartz, and some iron-pyrites and galena.

[1] The letters, indices, and calculated angles here given are those of Dana, 'System of Mineralogy,' 6th edit., 1892, p. 116.

[2] This specimen has been mentioned under argyrodite (Min. Mag., 1898, vol. xii, p. 13).

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Although Bolivia has long been famous for its richness in silver, comparatively few species of silver-bearing minerals have been identified. The principal silver-ore is argentiferous tetrahedrite. The present notes add miargyrite and pyrostilpnite (p. 328) to the list [1].

16. Jarosite from Chocaya, Dept. Potosi.

A small specimen (Brit. Mus. no. 86727) from this locality, presented by Mr. M. Roberts in 1903, has the aspect of ochre-yellow semi-opal, and had been mistaken for compact cassiterite. In cavities, the surface is mamillary and encrusted with very minute, sparkling crystals of a reddish-brown colour. A little granular galena is embedded in the opal-like mass. The crystals are optically uniaxial and negative, and the massive material is finely crystalline and birefringent. The specific gravity is 3·0, and the hardness about 4. A chemical examination made by Dr. G. T. Prior proved the material to be a hydrated sulphate of iron, potassium, and sodium, and therefore to be jarosite.

17. Chalybite from Chorolque and Tatasi.

Chalybite is of rather frequent occurrence in the mineral-veins of Bolivia, but usually only as small, indistinct crystals: it is invariably associated with iron-pyrites. Fine groups of large, bold crystals are found at the Cerro de Chorolque in province Sud-Chichas, department Potosi. A specimen (Brit. Mus. no. 86468), from the Hohmann collection, shows a number of crystals, measuring $3\frac{1}{2}$ cm. along their rhombohedral edges, grouped together on the flat surface of a dark-coloured, slaty rock: the group of crystals measures 20×10 cm. Between the chalybite and the rock is some black blende with metallic lustre and a little iron-pyrites. The crystals have the form of the rhombohedron $f\{\bar{1}11\} = \{02\bar{2}1\}$, with large flat faces faintly striated parallel to their longer diagonal. The edges are rounded by etching, and the faces are also dulled and roughened from the same cause. A surface coating of clay also detracts from the appearance of the crystals. In the interior, however, they are pale yellow, transparent, and clear. There are no indications of sub-parallel grouping or curvature of the crystals, as is so often the case in chalybite; and the cleavage-surfaces, which truncate the rhombohedral edges, are perfectly bright and smooth.

On another, similar specimen from the same locality, two of the large rhombohedra, $f\{\bar{1}11\}$, are twinned with interpenetration, the twin-plane

[1] In addition to the silver minerals from Aullagas mentioned above, crystals of stephanite have been described (Min. Mag., 1898, vol. xii, p. 6, footnote).

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being e (111) and the vertical axes of the two crystals coincident (fig. 11). The other crystals on the specimen are simple. This twin-law, though common in calcite and dolomite, is not mentioned in the textbooks for chalybite. On a third specimen the more deeply etched rhombohedra of chalybite form one side of a vein of bismuthinite (Bi_2S_3).

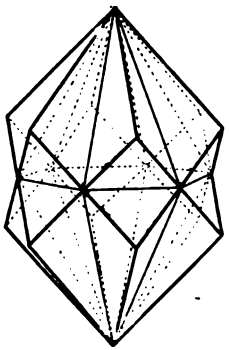

Fig. 11.—Chalybite from Chorolque.

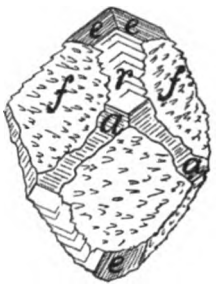

Fig. 12.—Chalybite from Tatasi, $f\{\bar{1}11\}$ twinned on (111).

Large crystals of chalybite are present on a specimen (Brit. Mus. no. 87096), also from the Hohmann collection, from the Tusti vein at Tatasi. The crystals (fig. 12), measuring 3 cm. across, are here associated with bright cubo-octahedra of galena. They have the forms r {100}, e {110}, a {10$\bar{1}$}, and f {$\bar{1}$11}. The faces r, e and a are striated parallel to the zone-axis [era]; the narrow e and a being deeply striated and uneven, while the larger r is plane. f is represented only by rough, somewhat cavernous areas formed by numerous small projecting faces which reflect light together with r, e, and a. Except on the smoother r faces, these large crystals have quite the appearance of being built up of small lenticular individuals with the forms r, e and a, the last being quite narrow. Several small crystals of this kind are present on the galena and on other parts of the specimen; these are pale yellow and transparent, while the larger crystals appear to be darker in colour.

Another type of chalybite crystals, more commonly met with at Tatasi, is that of small, slender spindles, 1 to 2 mm. in length. These are striated longitudinally, and under the microscope have quite the appearance of pin-points. They probably represent very acute rhombohedra with curved faces. When these crystals are dissolved in acid they leave an abundant residue of microscopic needles, which appear to be quartz.

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The best examples of these spindle-shaped crystals of chalybite are to be seen in the cavities of the massive miargyrite from Tatasi (p. 340). They form a strong contrast to the lenticular crystals of chalybite associated with the massive miargyrite from Colquechaca (p. 341).

The small crystals of chalybite associated with vivianite from Tasna (p. 325) have the form of acute rhombohedra, with or without the prism a {10$\bar{1}$1} : the faces, though plane, are too dull and drusy for their indices to be determined on the reflecting goniometer. The crystals with the augelite from Tatasi (p. 324) are short hexagonal prisms, m {2$\bar{1}$1}, terminated by r {100} and e {110}.

18. Enargite from Chorolque.

A specimen (no. 86467) in the British Museum collection is accompanied by a label in T. Hohmann's handwriting—'Enargite : Mina Coronacion, Chorolque'; and the same information appears in Hohmann's MS. catalogue. R. Pöhlmann, in his description of the Hohmann collection[1], mentions enargite from Argentina and from Chorolque in Bolivia in the form of columnar crystals 1 cm. in length.

The specimen shows a number of bright, well-developed crystals of enargite covering a surface of massive iron-pyrites and fahlerz. The only forms present are c {001}, a {100}, and m {110}, all of large size: a and m are vertically striated, and c is striated parallel to its intersection with a. The crystals are tabular parallel to a. Being closely grouped, and with the prism-edges approximately perpendicular to the underlying matrix, the crystals appear to be quite short in the direction of the vertical axis, and the bright basal planes produce a kind of tessellated surface to the specimen. The crystals measure about 1 cm. across the basal planes in their longer direction, and the bright prismatic cleavage surfaces at the edges of the specimen have about the same length.

The specimen is not unlike those from the Sierra Famatina in Argentina, but at the latter locality the crystals of enargite seem to be always associated with small crystals of quartz. I. Domeyko in his 'Mineralogia' makes no mention of enargite from Bolivia, but G. Bodenbender[2] gives Bolivia without any precise locality.

[1] Verh. Deutsch. wiss. Ver. Santiago de Chile, 1899, vol. iv, p. 80.

[2] G. Bodenbender, 'Los Minerales . . . en la República Argentina,' Córdoba, 1899, p. 54.

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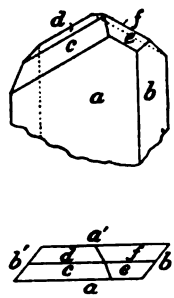
Cassiterite pseudomorphs from Bolivia[1].

By Richard Pearce, Ph.D., F.G.S.

[Read June 22, 1906.]

ONE of the peculiarities of Bolivian tin-ores is the frequent occurrence of cindery and cellular masses of cassiterite, which is presumably of secondary origin. But, apart from impressions[2] of quartz crystals, definite crystal-forms are rarely shown by this pseudomorphous cassiterite.

The pseudomorphs to be now described are from the Tres Cruces district[3], and were collected by my son, Mr. A. W. Pearce. The crystallographic determinations have been made by Mr. L. J. Spencer, and the specimens examined by him have been presented to the British Museum. The material consists of cavernous masses of dark brown, finely crystalline and granular cassiterite, associated with which is a pale yellow, ochreous substance. Some of the smaller cavities are bounded by plane surfaces, as if crystals had been dissolved out; while larger cavities are lined with pseudomorphous crystals. These are tabular in habit, and measure 2 to 4 mm. across by 1 mm. in thickness. Their surfaces have a drusy aspect, due to the crystalline development of the minute granules of cassiterite of which the material consists. Some of the pseudo-



Pseudomorph of cassiterite after an unknown mineral from Bolivia.

[1] A preliminary account has appeared under the title: 'Notes on the occurrence of pseudomorphs of oxide of tin after some unknown mineral from Bolivia,' by R. Pearce: Trans. R. Geol. Soc. Cornwall, 1906, vol. xiii, pp. 150-2.

[2] A. W. Stelzner (Zeits. Deutsch. geol. Ges., 1897, vol. xlix, p. 137) mentions cassiterite from Tasna with impressions of hexagonal prisms with basal plane, suggesting that, in this case, the original mineral was apatite. On p. 134 he mentions tin-ore from Chorolque with impressions of an octahedral (?) mineral. M. Roberts (Trans. Inst. Mining and Metallurgy, 1902-3, vol. xii, p. 404) also records the presence at Chorolque of sponge-like lumps of almost pure cassiterite with impressions of crystals. Finally, I. Domeyko (Bull. Soc. Min. France, 1882, vol. v, p. 299) makes mention of impressions of apatite (?) crystals in massive cassiterite from Bolivia.

[3] Tres Cruces (Three Crosses) or, in the Indian language, Quimza Cruz, is a mountain in the province of Inquisivi, department of La Paz, and is situated about 85 miles NNW. of Oruro.

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crystals are hollow, and encrusted inside with bright crystal-faces of cassiterite.

Only indistinct and blurred images are reflected from the faces, and even with the δ-eyepiece of the Fuess goniometer only approximate measurements could be obtained. Rather better results were obtained by thinly coating the pseudomorphs with copal-varnish. The angles measured on four crystals are given under I, II, III, and IV respectively.

	I.	II.	III.	IV.
ac	31°	31⅓°	33°	30¾
ad	80°	78¾°	78¼°	79°
ae	38°	38⅓°	—	—
af	101½°	101⅔°	102°	96°
ag	145°–149°	—	148°	150°
ah	24°–32°	—	—	—
ab	34°–40°	45°	45°	44½°

The plane angles on the face *a* were determined under the microscope to be approximately 120° on each of the four crystals; i. e. the angles between the zones [*acd*] : [*aef*] and between [*aef*] : [*ab*] = 60°.

Crystal I is represented in the accompanying figure; *g* is a narrow face on the edge *fa'*, and *h* is a rounded surface between *a* and *b*. Crystals II, III, and IV differ from no. I like the opposite ends of a monoclinic crystal, the faces *b*, *e*, and *f* being on the left-hand side of *a*. From the above table of angles it will be noticed that the angles in the zone [*acd*] are supplementary to those in the zone [*afg*], the measurements from *a* in one zone being approximately the same as those from the parallel face *a'* in the other zone: this proves the presence of a dyad axis of symmetry. The crystals are therefore monoclinic, with the plane of symmetry perpendicular to the faces *a* and *b*. They are tabular parallel to what may be taken as the basal pinacoid (*a*), and are attached at one or other end of the dyad axis.

In having plane angles of 120° on the basal plane, the crystals simulate rhombohedral symmetry, like the micas, polybasite and pearceite, xanthoconite, &c. The interfacial angles of the pseudo-crystals do not, however, correspond with the angles of any of these minerals. In general habit the pseudomorphs are not unlike axinite, but here again there is no correspondence between the angles. It must therefore remain doubtful what was the original mineral of these pseudomorphs.

Another suggestion as to what might have been the original mineral

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is given by the following partial analysis of the yellow ochreous material associated with the pseudomorphs:—

Fe_2O_3	28·24 per cent.
PbO	17·67
SO_3	16·70
As_2O_5	4·05
Insoluble (mainly cassiterite)	7·0

At 200° C. no loss.

The presence of lead suggests that the pseudomorphs may have originated by the alteration of a sulphostannate of lead. The occurrence of sulphostannates, viz. stannite, canfieldite, teallite, franckeite, cylindrite, and plumbostannite, is a peculiar feature of the silver-tin lodes of Bolivia; and, with the exception of stannite, none of them are known to occur outside this region. Although there is no agreement between the crystalline forms of these minerals and the pseudomorphs described above, it does not seem at all unlikely that some, at any rate, of the pseudomorphous cassiterite of Bolivia may have been formed by the alteration of sulphostannates.

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On the occurrence of Linarite and Caledonite in County Wicklow.

By Arthur Russell.

[Read March 20, 1906.]

TO the north-west of Rathdrum, in the county of Wicklow, three important groups of lead mines were formerly worked, which are known respectively as the Glendasan or Luganure, Glendalough, and Glenmalure mines, after the mountain glens in which they are situated. The lodes traverse the granite in a north and south direction close to its junction with the mica-schist, and are somewhat remarkable for the variety of their mineral contents.

During the summer of 1904, while examining the old burrows of the Moll Doyle mine in the vale of Glendasan, I came across two or three small specimens of a quartzose vein-stuff showing spots of chalcopyrite, malachite, and a deep azure-blue mineral. The quantity of the blue mineral was too small for a chemical examination, and I was unable to determine the species, but the general appearance and association at once recalled the linarite of Red Gill in Cumberland.

In February, 1906, I revisited the district, and while searching on the burrows of the Ballinafunshoge mine in the vale of Glenmalure, some four miles to the south of the Glendasan mines, I was fortunate enough to find several larger and more clearly defined specimens of the blue mineral. A qualitative chemical test made on one of these proved the mineral to be linarite. Two of the specimens show sharp, though minute, characteristic prismatic crystals, about 1 mm. in length, flattened parallel to s (101) and elongated parallel to the edge of the zone [ac]. The forms present are a {100}, c {001}, s {$\bar{1}$01}, m {110}. For the identification of the forms I am indebted to Dr. G. F. Herbert Smith, who, at my request, kindly measured one of the crystals. In the case of the Ballinafunshoge specimens the associated minerals are a peculiar black cerussite, malachite, and yellowish quartz. On two of the specimens the linarite occurs as small, indistinct crystals forming a crust on a decomposed granitic rock.

Associated with the linarite from the Moll Doyle mine there is, in

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addition to chalcopyrite and malachite, a very small quantity of a pale greenish, pearly mineral, which is most probably aurichalcite.

The caledonite, of which only one specimen was found, occurs associated with the linarite as minute, though characteristic, bluish-green crystals implanted on the black cerussite from the Ballinafunshoge mine. The mineral was determined by a qualitative chemical test. The crystals were too intergrown and the faces too uneven to allow of crystallographic measurement.

Since the publication in 1868 of Townshend M. Hall's 'Mineralogist's Directory', comparatively few additions have been made to our knowledge of Irish mineral localities. I am therefore pleased to be able to add the names of two minerals which I believe to be new to that country. The two species are not included in the preliminary and supplementary lists of Irish minerals given by Mr. Henry J. Seymour in the British Association Reports for 1902 and 1903.

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Note on the mines and minerals of the Silvermines district, Co. Tipperary.

By Arthur Russell.

[Read March 19, 1907.]

THE Silvermines mineral district is situated along the northern base of the Silvermine Mountains, five and a half miles south of the town of Nenagh in the county of Tipperary. The district is one which possesses somewhat remarkable features, of interest to both geologists and mineralogists. The mines extend over a narrow tract of country for a distance of about five miles along an extensive E. and W. line of fault, in which Silurian, Old Red Sandstone, and Carboniferous rocks are brought into juxtaposition. This line of fault has been traced for a distance of about thirty miles from Gallows Hill in co. Clare, on the west, to Toomavara in co. Tipperary, on the east. Along its course in at least two places mineralization has taken place, resulting in a somewhat complex series of contact-lodes and metasomatic deposits.

Mining operations in search of silver-lead were evidently carried on at Silvermines at a very early date, the whole district being literally honey-combed with ancient open workings, shafts, and levels. Actual records date back to the year 1600, and mining was carried on intermittently down to 1800. The mines were then taken over by the General Mining Company of Ireland, which carried on extensive operations down to 1870. Since that date, little or nothing has been done beyond the clearing up, a few years ago, of a shaft and the raising of a small quantity of calamine-ore at Ballygown South mine.

The general geology and many features of the mines of this district have been very ably described in the Explanations accompanying Sheet 134 of the Irish Geological Survey, which was published in 1861. I purpose, therefore, to deal mainly with the mineral contents of the lodes, as exemplified by specimens lately found by myself on the old mine burrows. As is usual in Ireland, the mines are mostly named after the township in which they are situated. Commencing with the most easterly of the group and going westward, we will consider any points of mineralogical interest.

Just south and close to the little village of Silvermines lies the *Ballygown South mine*. Here, along the line of fault, the Carboniferous

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Limestone is brought down against the Old Red Sandstone; the former rock being converted into a hard, grey, crystalline dolomite, extending in places as a narrow strip along the north side of the fault, and passing insensibly into the surrounding Carboniferous Limestone. Running at right angles to this strip of dolomite, and dipping about 10° N. below the limestone on which the village stands, is a very remarkable bed of rusty ochreous gossan about 20 feet thick. Both the foot-wall and hanging-wall are entirely composed of dolomite, whilst the gossan itself frequently contains great irregular rounded masses of dolomite; these in all probability having resisted the general metasomatic action. The bulk of the gossan is composed of cellular and sponge-like masses of brownish-yellow limonite, the cavities and surfaces of which are often lined with drusy crusts and brilliant crystals of hemimorphite (calamine). In other cases the hemimorphite forms with galena solid, irregular lumps, often of considerable size, the exterior and cavities being studded with crystals. The calamine-ore was first discovered by Captain Thomas King, the resident manager of the mines, who in 1858 sent a sample taken from the bottom of an ancient shaft to Dublin, where it was examined by Dr. Apjohn. The latter analysed the mineral, and showed it to be basic silicate of zinc, or hemimorphite[1].

The hemimorphite crystals, though of comparatively small size (the largest noted being 2 mm. long), are wonderfully brilliant and sharp. They resemble the well-known Aix-la-Chapelle specimens, and are fairly rich in faces about the analogous pole. The crystals are tabular parallel to the brachypinacoid, *b* {010}, the *b* face being vertically striated. They are usually attached to the matrix by the antilogous pole; in a few cases, however, both poles are developed. The following forms were noted: *b* {010}, *c* {001}, *m* {110}, *t* {801}.

The deposit of calamine-ore at Silvermines is of especial interest as being the only occurrence of the kind known in the United Kingdom. In many of its features it presents great similarity to the well-known deposits at Moresnet in Belgium. From the fact that small quantities of blende and galena have from time to time been found amongst the zinc-bearing gossan, it seems probable that the metallic contents were originally deposited in the form of sulphides along the line of fault and

[1] J. Apjohn, 'On the occurrence of electric calamine at the Silver Mines, County of Tipperary.' Journ. Geol. Soc. Dublin, 1860, vol. viii, pp. 157–9. See also A. B. Wynne, 'Some remarks upon the mining district of Silvermines, County of Tipperary, with a map.' ibid., pp. 244–50; J. Beete Jukes, 'Note on the way in which the calamine occurs at Silvermines, County of Tipperary.' ibid., 1863, vol. x, pp. 11–18.

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side-fissures. Subsequently, underground waters by their metasomatic action brought about the gradual substitution of the surrounding limestone by silicate of zinc and oxide of iron. The existence of large quantities of barytes would point to an intermediate stage in which the sulphur of the sulphides underwent oxidation.

In addition to the hemimorphite, the gossan often contains irregular masses of galena, partially altered to cerussite, and occasionally small quantities of blende. The galena was said to contain 80 ounces of silver to the ton. Barytes is also of frequent occurrence either in curious radiating and stalactitic masses, the exterior coated with pale yellow, earthy limonite, or in aggregations of simple wedge-shaped crystals ($c\{001\}, m\{110\}$) grouped in parallel position. Smithsonite (zinc carbonate) is said to have occurred in the gossan, but I failed to detect this mineral.

Adjoining the Ballygown South mine, and a little to the south, is a large contact-lode, composed mainly of pyrite, known as the *Sulphur mine*. Old Red Sandstone forms the southern wall, whilst the northern is composed of dolomite. Large quantities of pyrite were formerly raised here, but nothing of mineralogical interest presents itself.

At the *Gortshaneroe* or *Ballynoe mine*, chalcopyrite, galena, and barytes form a lode between walls of Silurian and Carboniferous Limestone rocks. Close to this spot in the bed of a stream is a remarkable deposit of barytes said to contain spots of pyrite and orpiment. This occurrence of orpiment was recorded in 1860 by Mr. Alphonse Gages[1].

At the *Gorteenadiha* or *Gortnadyne mine*, very extensive mining operations were formerly carried on, principally for copper, although a considerable quantity of lead was also raised. The principal lode lies between Old Red Sandstone and Carboniferous Limestone. The vein-stuff consists of a hard quartz-sandstone-breccia, containing irregular patches of chalcopyrite, whilst in places argentiferous tetrahedrite is abundant, and may be found on the old burrows associated with large masses of white barytes. The barytes is particularly abundant at this mine, and is often very pure. Good specimens of white acicular cerussite (called by the miners 'cat-tooth-ore'), often stained with malachite or azurite, are common.

The once important mines of *Shallee East* and *Shallee West* form the limit on the west on which mining operations have been carried out.

[1] A. Gages, 'On the formation of orpiment in a mass of sulphate of barytes, found interstratified in the Carboniferous Limestone near Silvermines, County of Tipperary.' Journ. Geol. Soc. Dublin, 1860, vol. viii, pp. 243–4.

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The Shallee East mine presents a very remarkable appearance, the whole base of the mountain-side being furrowed with a very extensive series of open workings made in search of lead-ore. These open workings vary in width from 8 to 6 feet, and occasionally extend for a distance of 80 yards; they average about 30 feet in depth. Their direction is more or less at right angles to the main line of fault, and they evidently represent a series of side fissures in which mineralization has taken place from a common source. The enclosing rock is a dirty grey, quartzose sandstone. The galena occurred more or less intimately associated with white, massive barytes, the latter mineral forming a large portion of the vein-stuff. Argentiferous tetrahedrite and cerussite are also present in small quantities.

The compact nature of the vein-stuff and the absence of vugs have precluded the formation of crystallized minerals, which, with the exception of hemimorphite and barytes at Ballygown South mine, appear to have been of extremely rare occurrence in this district.

List of Minerals occurring in the Silvermines district, co. Tipperary.

Ballygown South mine (Calamine mine):—
Hemimorphite (Calamine), Smithsonite ? Blende, Galena, Cerussite, Pyrite, Limonite, Barytes.

„ „ „ (Sulphur mine):—
Pyrite, Galena, Blende.

Gortshaneroe or Ballynoe mine:—
Galena, Chalcopyrite, Pyrite, Orpiment, Barytes.

Garryard West mine:—
Galena, Cerussite, Pyrite.

Gorteenadiha or Gortnadyne mine:—
Chalcopyrite, Tetrahedrite, Malachite, Azurite, Galena, Cerussite, Blende, Hemimorphite, Pyrite, Barytes.

Shallee East or Shallee Coughlan mine:—
Galena, Cerussite, Tetrahedrite, Barytes.

Shallee West or Shallee White mine:—
Galena, Barytes.

The following additional minerals from this district are mentioned by Townshend M. Hall in his 'Mineralogist's Directory', 1868:—Erythrite at Silvermines; Pyromorphite at Shallee Mountain.

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A new model of Refractometer.

By G. F. Herbert Smith, M.A., D.Sc., F.G.S.
Assistant in the Mineral Department of the British Museum.

[Read January 29, 1907.]

THE instrument described in this paper is identical in principle with the small refractometer[1] designed by the author more than three years ago, but differs from it in several details which are of considerable practical importance. As in the earlier form, a compensative lens is introduced of such curvature and focal length that the focal surface of the optical combination is a plane within the range for which the instrument is required, and consequently the critical edges are sharply defined in monochromatic light for all positions. It will be more convenient, before entering into the description, to take the features which have been changed.

1. As will be seen from the illustration (fig. 1), the aspect of the refractometer has been completely altered. The awkward corner existing close to the dense glass in the earlier form has been obviated, and now the whole of the parts lie on the same side of the plane of the brass plate carrying the dense glass which forms the constant medium; there is, therefore, practically no limit to the size or to the shape of a stone for which the instrument may be used, and it matters not if it be surrounded by a wide setting. In the case of the earlier instrument the table-facet of a large stone, or of one mounted, for instance, in a brooch, often could not be brought on to the plane surface of the dense glass. Of course, a small facet would answer the purpose equally well; but the author is aware, from experience, of the difficulty of assuring that a small facet of a large stone is pressed evenly against, and not inclined to the surface of the glass. Any such uncertainty might render the observations valueless, and, moreover, there is great risk of scratching the surface of the dense glass. The same kind of difficulty not infrequently arises in the case of jewellery.

2. The instrument is larger in size; indeed, the focal length is precisely double what it is in the smaller form, and delicacy of the readings has been correspondingly increased.

[1] Min. Mag., 1905, vol. xiv, pp. 83–6.

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3. The scale (fig. 2) is no longer arbitrary, but gives the refractive indices for sodium-light directly to the second place of decimals, and the intervals are such, particularly in the higher values, that the tenth parts may be estimated with some certainty, and a trustworthy value, therefore, obtained of the indices to the third place of decimals. Previously the scale was quite arbitrary and had to be calibrated by means of observations of substances of known refractive indices, and after an observation had been taken reference had to be made to a card on which was given the equivalents in refractive indices of the divisions on the scale. If the card were lost, the instrument was useless until it had been recalibrated. At the same time the range has been increased by at least a whole unit in the second place of decimals, and extends now to 1·770. The limit varies slightly with the instrument, depending as it does on the amount to which the plane surface of the dense glass projects beyond the brass plate embracing it, and may be as high as 1·775. In the earlier form the higher limit is rarely much above 1·750 and never exceeds 1·760. The extension is of extreme importance, since the range now includes the refractive indices of corundum, a species which occupies such a prominent place among gem-stones that the direct determination of the refractive power greatly increases the utility of the instrument. In the earlier refractometer it was, indeed, possible to see in white light the violet end of the coloured edge

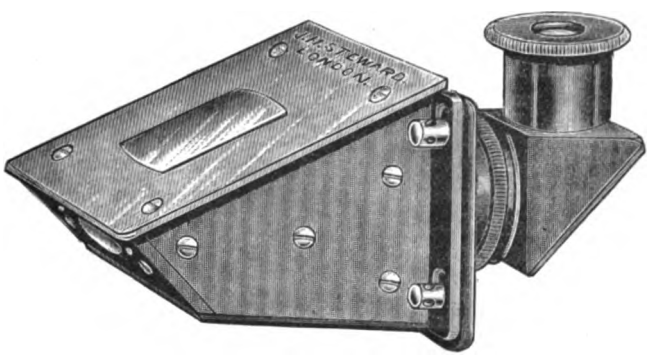

Fig. 1.—Refractometer (actual size).

corresponding to the extraordinary index in the case of all save the deep-red stones; but bright daylight was required for a trustworthy observation, and such a determination cannot be considered so satisfactory as an actual measurement of the refractive indices.

4. A lens, of one inch (25 mm.) focal length, has been substituted for

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the ground-glass plate through which light is admitted to the instrument. Owing to the extreme shortness of the focal length of the telescope—as optically considered the instrument really is—the image of the surface of the ground-glass plate is formed so near the focal plane as to be within the accommodating power of the observer's eye, and consequently not only is an exact appreciation of the position of the critical edge rendered difficult, owing to the apparent diffusion of the edge, but a course of observations becomes most fatiguing by reason of the incessant change in the eye's focal adjustment. The lens throws outside objects, such as window-bars, the sodium-flame, &c., sufficiently out of focus that no inconvenience is experienced. If white light be employed, the most satisfactory illumination is obtained by using the diffused light reflected from a sheet of white paper laid on a table.

Fig. 2.—Scale of Refractometer.

It will simplify the description of the refractometer as regards the orientation of the various parts, if we suppose that the divisions of the scale are horizontal, whence it results that the optic axis of the combination formed by the dense glass and the compensative lens is also horizontal, and, further, if we suppose that we are viewing the instrument from the end, having the eye-piece towards us.

The constant medium, with which in a total-reflectometer the substance under examination is compared, is a highly refracting glass having an index for sodium-light of 1·7902. A denser glass, of refractive index 1·8924, is used in the type of total-reflectometer of greater precision which possesses rotational parts; but it is unfortunately so soft, fragile, and wanting in durability as to be little adapted to the purposes of a determinative instrument in constant use. Even in the case of the less dense, but more durable glass, great care must be taken not to scratch the surface when observations are made on the far harder gem-stones.

The glass is cut to the shape of a hemisphere, 1 cm. in radius, which is sliced vertically and symmetrically with regard to its centre to a convenient width, slightly exceeding that of the part of the field utilized. If desired, the shape may be a portion of a semi-cylinder, the circular section of which has the same radius, viz. 1 cm. The brass plate surrounding the dense glass is cut away and bevelled so that the plane surface of the latter projects slightly above the plate. The glass is firmly held in position from the two sides, but can be

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readily removed for repolishing without any risk of injury. In the case of the earlier instrument the dense glass is fitted in from above and burnished into position; i. e. a thin strip of metal is turned over the bevelled edge of the glass. Owing to its brittle nature, it is an operation of extreme delicacy thus to fix the glass in the right position, and, when once fixed, it cannot be removed without almost certain damage.

The brass plate, just mentioned, forms the top of the box, quadrilateral in shape when viewed from the side, which contains in addition to the dense glass the compensative lens. Of the sides of the quadrilateral figure, the base is horizontal; the right-hand side is vertical; and it and the left-hand side make equal angles, viz. 61°, with the upper side, i. e. the brass plate surrounding the dense glass. The left-hand side contains the lens through which light is admitted to the instrument. The right-hand side is the plate which is attached by means of four screws passing through holes in it, slotted vertically, to the corresponding plate which carries the scale and the eye-piece, and the former plate is cut away in the centre to admit the tube carrying at its inner end the scale. The upper plate is attached to the sides of the box, as may be seen from the figure, by means of four countersunk screws, which pass through holes in it slotted lengthwise—a means for varying slightly the distance between the dense glass and the compensative lens. The plate is hollowed out underneath from front to back, i. e. lengthwise, about the width of the dense glass in order to extend the range of the instrument as high as possible.

The compensative lens is carried in a frame, which may be moved up and down in two vertical grooves, fixed to the side plates, the motion being given by a screw, the head of which emerging through the bottom plate is actuated by a key and is covered by a cap to prevent accidental interference with the adjustment. The frame itself is cut away at the top so that the lens may fit into the groove hollowed out of the upper plate, the curvature of which is such as to accommodate the lens.

The tube, which carries at its inner end the scale, may be pushed in or out of the fixed tube surrounding it in order to bring the scale into focus and rotated to bring it upright, i. e. the divisions horizontal, and is held rigidly, when in the correct position, by means of a clamp of the ordinary split-ring type. The top of the tube at the inner end is filed away so that the top of the scale, or the bottom as seen in the eye-piece, may fit into the groove in the upper plate.

The scale, as has been stated above, gives the refractive indices for sodium-light direct to the second place of decimals, and the graduation

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extends from 1·300 to 1·775. The intervals between the divisions increase in size with the index, and to facilitate the estimation of the tenth parts the intervals from 1·650 upwards have been bisected. All the lines are drawn from the centre of the field towards the left, and every fifth is distinguished by its greater length. The readings are intended to be taken just at the point where the critical edge meets the right-hand edge of the scale, i. e. in the centre of the field; for, when the curved surfaces of the dense glass and the compensative lens are spherical, the critical edges are slightly curved, being circular arcs, and it is, of course, essential to know what part of the curve is to be observed. The difficulty does not arise in the case of cylindrical surfaces, because the edges are straight.

The eye-piece is of the ordinary positive type and magnifies about ten times; for convenience of observation a totally-reflecting prism is inserted between the two lenses. Since the eye-piece cannot be pulled out far without consequent unsteadiness, an adaptor can, if desired, be provided for observers with long sight.

In order to maintain during observation the stone in position upon the plane surface of the dense glass, and especially to minimize the risk of the stone falling off the instrument, light springs of German silver are provided. They are shaped like the Greek letter Ω, so as to grip the sides of the instrument, and vary in length to suit different sizes of stones.

All the instruments are made as closely as possible to the same pattern; but, of course, certain adjustments are necessary, which are as follows:—

1. The scale is fixed into its frame in as nearly as possible the same position in each instrument. To bring it into the correct position in the focal plane, the compensative lens is first screwed up until almost in contact with the upper plate; the screws holding the two parts of the instrument together are then slightly released, and the two parts moved relatively to each other in a vertical direction until the reading of the scale for the critical edge given by some known, preferably in all these preliminary tests singly refractive, substance is within a division of the truth; the final adjustment is effected by means of the screw adjustment to the compensative lens.

2. The focal length of the optical combination must be the same in all cases, because otherwise a troublesome correction to the readings of the scale would be necessary. The curvatures of the surfaces of the dense glass and of the compensative lens are invariable, and the only adjust-

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ment required, viz. the distance between the two constituents of the optical combination, is provided for by the slotting of the holes in the upper plate.

Unless there has been some error in the workmanship, the correct adjustment of the refractometer presents little difficulty. The scale is first brought into the focal plane and rotated until the divisions are horizontal, and is then securely clamped; as a criterion the critical edge given by some known substance is employed. The scale is next adjusted vertically in the manner described above until the reading for the edge is correct. Readings are now taken for two substances which give edges near the opposite ends of the scale. If the readings cannot be made simultaneously correct, the interval between the dense glass and the compensative lens is varied to the extent required. A last glance to see that all the screws are properly tightened, and the refractometer is ready for use.

This refractometer, like the earlier form, is the work of the well-known optician, Mr. J. H. Steward, 457 West Strand, London, W.C. To Mr. John Steward of that firm the author acknowledges an especial debt of thanks for many valuable suggestions for overcoming the various difficulties which almost inevitably arise in the construction of a new form of instrument.

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A simple arrangement and notation of the thirty-two classes of symmetry based on the symmetry of zone-axes.

By JOHN W. EVANS, LL.B., D.Sc., F.G.S.
Adviser in Mineralogy to the Imperial Institute and Lecturer on Mineralogy at Birkbeck College.

[Read January 29, 1907.]

IF a straight line making an angle with a zone-axis of a crystal be rotated about the zone-axis while the crystal remain fixed, the physical characters of that line will pass through a cycle of changes. If these changes repeat themselves n times during the course of a complete revolution, the zone-axis is said to have an nth-turn or n-fold cyclic symmetry. If the line be at any time normal to a crystal-face it will be normal to a face with the same physical characters n times during such a revolution.

If the order of succession of the changes be dependent on the sign of the direction of rotation, the zone-axis is said to be 'unilateral' or 'haplo-cyclic': if the order be the same for opposite directions of rotation, it is 'bilateral' or 'amphi-cyclic'[1].

The symmetry *round* a zone-axis, or its cyclic symmetry, may therefore be expressed by the cyclic number of the zone-axis, which may be I, II, IV, III, or VI, and its character whether unilateral (U) or bilateral (B).

A zone-axis has two opposite longitudinal directions. The termination corresponding to one of these may be defined as the aggregate of all straight lines making an angle of less than a right angle with such direction—as well as the faces to which any of such lines are normal. The two terminations of a zone-axis may be expressed by means of the zone symbols thus: T [uvw] and T [$\bar{u}\bar{v}\bar{w}$].

The symmetry *along* a zone-axis, or its 'longitudinal' symmetry, expresses the relation between its two terminations.

If there be no symmetry connecting the two terminations, other than symmetry round the zone-axis, the terminations will be unlike and the

[1] The number of the planes of symmetry passing through a bilateral zone-axis is that of its cyclic symmetry. If this number be odd, they are all like; if it be even, they fall into two equal groups of unlike planes. A unilateral zone-axis has no planes of symmetry passing through it.

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zone-axis is said to be uniterminal (u). In this case, if the zone-axis be unilateral, the crystal and its reflexion are not superposable.

If the two terminations of a zone-axis are similar it is said to be biterminal. In such cases the terminations may be related in different ways.

If one termination be the reflexion of the other in a plane of symmetry at right angles to the zone-axis, the longitudinal symmetry is said to be reflected (r).

If one termination can be derived from the other by reflexion and a half turn round the zone-axis, the axis is said to have 'longitudinal half turn' or 'central' symmetry (c). The crystal has symmetry about a point, and opposite directions on any straight line have the same physical characters. If the number of the cyclic symmetry be even, reflected and central symmetry are identical.

If one termination be derived from the other by reflexion and a quarter turn, the axis has 'longitudinal quarter turn' symmetry (q). It can be easily shown that this only gives rise to new forms of symmetry if the number of cyclic symmetry be II; in other words, if there be a half turn symmetry round the zone-axis. It can be also shown that longitudinal one-third turn and one-sixth turn symmetries give no new forms.

In all cases where the longitudinal symmetry of a unilateral zone-axis involves reflexion with or without rotation the two terminations are not superposable, but the crystal and its reflexion are superposable.

One termination may also be derived from the other by rotation through a half circle on a zone-axis at right angles to the original zone-axis. If the symmetry round the axis be bilateral, the relation between the terminations will be the same as in the case of central symmetry. New forms of symmetry are therefore only obtained when the cyclic symmetry is unilateral. In such cases the longitudinal symmetry may be referred to as 'helical' (h), because the two terminations are related in the same manner as the ends of a screw[1]. The terminations are superposable, but a crystal and its reflexion are not superposable.

[1] The number of secondary axes will be equal to that of the cyclic symmetry of the original axis. If that be odd, they will be all alike and uniterminal. If it be even, there will be two equal groups of unlike helical axes.

If a straight line at right angles to a helical zone-axis be rotated about it, the order of succession of changes of physical characters will be the same for opposite directions of rotation, except that the relation of such characters to opposite ends of the zone-axis will be reversed. In like manner and subject to a similar proviso, the faces of a helical zone exhibit the same succession in opposite directions. These relations do not exist in the case of other unilateral zone-axes.

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The full symmetry of a zone-axis may therefore be expressed by the conjunction of the different kinds of symmetry which it exhibits, and be indicated by the association of their symbols; thus the symmetry of the principal axis of idocrase may be described as 'fourfold' or 'quarter turn' 'bilateral central', or it may be more briefly and conveniently referred to by the symbol IVBc. If desired for the sake of brevity, the words 'whole turn' and 'unilateral' may be omitted, thus the symmetry of the principal axis of scapolite or scheelite may be described as 'quarter turn unilateral central' or simply 'quarter turn central', but the full symbol IVUc should always be used. The symmetry of a zone-axis of crystals of the asymmetric, calcium thiosulphate, class would be 'whole turn unilateral uniterminal' or simply 'uniterminal,' with the symbol IUu.

The thirty-two classes of crystal-symmetry may be distinguished by the symmetry of the zone-axis having the highest number of cyclic symmetry and may be referred to by the corresponding symbols. Those classes which have four axes of threefold or one-third turn cyclic symmetry are said to be 'cubic' with the symbol 4III or C.

The classes are first grouped by the number of the characteristic cyclic symmetry, the cubic classes forming a separate group. These groups are subdivided, first, according as the cyclic symmetry is bilateral and unilateral, and secondly, by the character of the longitudinal symmetry.

In the first table which accompanies this paper each class is represented by its symbol accompanied by the name of a substance crystallizing in it, when such is known to exist. The classes with the same number of cyclic symmetry are arranged vertically, and those that agree in their unilateral or bilateral character and longitudinal symmetry horizontally[1]. It will be seen that all the vertical columns except that of the whole turn symmetry have *unilateral* uniterminal, helical, and central symmetry and *bilateral* uniterminal and central symmetry. These give $5 \times 5 = 25$ classes; the whole turn column has three classes, and the half turn column and one-third turn column have each two extra classes, making the full total of thirty-two classes.

In the second table, each symbol is followed by the crystallographic system and the number of the class according to Professor Lewis ('Crystallography,' 1899) and Professor Miers ('Mineralogy,' 1902, p. 280).

This classification presents many points of resemblance to those of

[1] It is convenient to arrange the different kinds of longitudinal symmetry in an order different from that in which they have been described.

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TABLE I.

	Whole turn.	Half turn.	Quarter turn.	One-third turn.	One-sixth turn.	Four one-third turns or Cubic.
	I.	II.	IV.	III.	VI.	4III or C.
UNILATERAL (U).						
Uniterminal (u).	IUu Calcium thiosulphate.	IIUu Cane sugar.	IVUu Wulfenite.	IIIUu Sodium periodate.	VIUu Nepheline.	CUu Ullmannite.
Biterminal						
Helical (h).	(*See IIUu*)	IIUh Sulphur.	IVUh Strychnine sulphate.	IIIUh Quartz.	VIUh Barium antimonyl dextrotartrate + potassium nitrate.	CUh Cuprite.
Central (c).	IUc Albite.	IIUc Augite.	IVUc Scapolite.	IIIUc Dioptase.	VIUc Apatite.	CUc Iron-pyrites.
Reflected (r).	(*See IBu*)	—	—	IIIUr (Unknown).	—	—
Quarter turn (q).	—	IIUq (Unknown).	—	—	—	—
BILATERAL (B).						
Uniterminal (u).	IBu Clinohedrite.	IIBu Hemimorphite.	IVBu Succinimide.	IIIBu Tourmaline.	VIBu Iodyrite.	CBu Tetrahedrite.
Biterminal						
Central (c).	(*See IIUc*)	IIBc Olivine.	IVBc Idocrase.	IIIBc Calcite.	VIBc Beryl.	CBc Galena.
Reflected (r).	(*See IIBu*)	—	—	IIIBr (Unknown).	—	—
Quarter turn (q).	—	IIBq Copper-pyrites.	—	—	—	—

TABLE II.

Symbol.	System.	Lewis.	Miers.	Symbol.	System.	Lewis.	Miers.
IUu	Triclinic	I	1	IIIUu	Rhombohedral	I	9
IUc	,,	II	2	IIIUh	,,	IV	10
IBu	Monoclinic	II	3	IIIUc	,,	II	15
IIUu	,,	I	4	IIIUr	,,	VI	11
IIUh	Orthorhombic	I	6	IIIBu	,,	V	12
IIUc	Monoclinic	III	5	IIIBc	,,	III	19
IIUq	Tetragonal	VII	22	IIIBr	,,	VII	13
IIBu	Orthorhombic	III	7	VIUu	Hexagonal	I	14
IIBc	,,	II	8	VIUh	,,	V	16
IIBq	Tetragonal	I	26	VIUc	,,	II	17
IVUu	,,	III	21	VIBu	,,	III	18
IVUh	,,	V	23	VIBc	,,	IV	20
IVUc	,,	IV	24	CUu	Cubic	III	28
IVBu	,,	VI	25	CUh	,,	I	29
IVBc	,,	II	27	CUc	,,	IV	30
				CBu	,,	V	31
				CBc	,,	II	32

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Professor Miers and Mr. H. Hilton[1]. The latter I had not seen when I read this paper. I recognize the justness of his contention that a centre of symmetry is more fundamental than a plane of symmetry. The chief merit I claim for the present arrangement is that it will be easily apprehended, remembered, and applied by the student. If thought fit Professor Miers's terms 'digonal,' 'tetragonal,' 'trigonal,' 'hexagonal,' and 'tesseral' may be substituted for II-, IV-, III-, and VI-turn, and cubic respectively, and 'di-' prefixed to indicate a bilateral character of the axis. The only difficulty is that some of these expressions have already been widely used in other senses.

By far the most convenient method of referring either viva voce or in writing to any class will be found to be its symbol. Thus quartz may be said to crystallize in IIIUh class; iron-pyrites in the CUc (Cubic Uc) class.

[1] Min. Mag., 1907, vol. xiv, p. 261.

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On a Serpentine-rock from the mass of the Tarnthaler-Köpfe, Tirol.

By A. P. Young, Ph. D., F.G.S.

[Read January 29, 1907.]

THE rock-specimens here treated were collected in 1902 on a small plateau near the head of the Oberer-Bach, where the rock is in place. This stream, rising near the Röckner or Reckner, a summit of the Tarnthaler-Köpfe on the north of the Tuxerthaler mass, flows down a steep ravine southward to join the Schmirner-Bach: the locality is situated about 20 kilometres to the south-east of Innsbruck. The figures 2629 (height in metres) on the 'Generalstabskarte' probably represent the site of the plateau; it is on the right bank of the stream, close to, and some 12 or 15 metres above, a small frozen lake near the head of the stream. The point was reached by ascending the ridge from the Kreuzjöchl. There was much snow on the plateau and the geological relations of this particular occurrence were not observed.

The two specimens which I collected on the above-mentioned plateau of the Tarnthaler mass show considerable differences in the proportions of the minerals present. One is rich in colourless pyroxene, and contains but little amphibole and picotite. The other contains much amphibole (probably tremolite), clinochlore, much picotite, and little pyroxene. The conspicuous bastites are more numerous in the rock with much pyroxene. The serpentine-minerals exhibit similar characters in the two specimens.

Pyroxene.—The colourless pyroxene, as seen in thin sections of both the specimens, is remarkable for the complete absence of twinning and zoning. Sections of crystals showing the typical prismatic cleavage give, in convergent light, a positive interference-figure around one of the optic axes, and the optic axial plane is seen to bisect the acute angle between the cleavages. Sections which show the interference-figure of an optic normal give an extinction-angle $c : \dot{c} = 40°$.

Sometimes the pyroxene forms a core of the larger amphibole crystals to be mentioned below. Inclusions are present in some of the pyroxene crystals; they have the form of short rods arranged in swarms with

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their longer axes parallel to the orthopinacoid of the pyroxene, and their refractive index differs but little from that of the host. Or again, some of the pyroxene crystals show undulose extinction; whilst groups of small grains all differing in optical orientation are no doubt in many cases the displaced fragments of a single crystal ('Mörtelstruktur').

This pyroxene seems to be an original consolidation product of the igneous magma, and it resembles the sahlite noted by Hussak[1] in other Alpine serpentines. It has in part been altered to serpentine. Sinuous veins of a pleochroic serpentine traverse the pyroxene crystals in all directions, giving them quite the appearance of decomposing olivines. Only in the absence of iron oxide do these veins differ from those in the surrounding serpentine. The slides were carefully searched for olivine, but this mineral could not be detected[2]. Dull opaque masses of a dark-brown colour and traversed by numerous cracks are not infrequent, and sometimes suggest a derivation from olivine.

Rothpletz[3] records the presence of fresh olivine in the neighbouring serpentine-mass of the Röckner, and von Drasche[4] mentions kernels of the same mineral in serpentinous decomposition products in boulders (which may not, however, belong to this district) at Brixlegg. Reports of other occurrences of olivine in the serpentine-rocks of this district (e.g. at Matrei-am-Brenner and Pfons) appear to be based merely on the structures observed in the serpentinous decomposition products. Seeing, however, how closely the serpentine-veins in decomposing pyroxene crystals may simulate in form the network in altered olivines, the question arises as to how far such conclusions are justifiable.

Amphibole (*Tremolite*).—The mineral is colourless in thin sections, sometimes appearing in compact crystalline form, but more often showing the sheafy habit of secondary amphiboles. The prismatic cleavage is distinctly shown in some of the sections. The needles in the sheaves are sometimes twinned according to (100). Sections showing an emergence of an optic normal have not been found; the highest angle

[1] E. Hussak, 'Ueber einige alpine Serpentine.' Min. Petr. Mitt. (Tschermak), 1883, vol. v, pp. 61–81.

[2] The fact that the pinacoidal cleavage (010) of olivine is perpendicular to the optic axial plane helps to distinguish this mineral from pyroxene; for in sections of the latter, in which the prismatic cleavage is shown as parallel cracks, the trace of the optic axial plane is parallel to these.

[3] A. Rothpletz, 'Ein geologischer Querschnitt durch die Ost-Alpen.' Stuttgart, 1894, pp. 83, 84.

[4] R. von Drasche, 'Ueber Serpentine und serpentinähnliche Gesteine.' Min. Petr. Mitt. (Tschermak), 1872, Jahrg. 1871, pp. 1–12.

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of extinction observed is 17°, the axis of less elasticity being nearer the axis of the needle.

The larger crystals of amphibole are traversed by sinuous veins of serpentine, whilst the needles are decomposed at the ends into a bastite-like mineral to all appearance identical with the mineral *A* described below.

The occurrence of amphibole with a core of pyroxene recalls a similar relation in the diabases of Vahrn, near Brixen in southern Tirol. In the tendency to form sheaf-like aggregates the mineral resembles more nearly that of the amphibolites, and is probably to the same extent an original product, either a first crystallization or a very early product of molecular reconstruction in a deep-seated rock-mass.

The decomposition into serpentine-like products proves this amphibole to be older than the serpentine. Lindemann[1] considers an amphibole in a rock of the serpentine group near Sterzing in the Tirol to be secondary and contemporary with the serpentine.

Clinochlore.—A colourless, non-pleochroic mineral of the chlorite group is found only in the slide with much amphibole. It gives low grey polarization-tints and has an index of refraction distinctly higher than that of the serpentines, but lower than that of the amphibole. Twinning with the basal plane as face of composition is frequent. Extinction angles up to 5° have been measured against the trace of (001). The axis of less elasticity is always normal to the cleavage plane, and the 'isogyres' of Becke give indications of a positive optical character for the crystals.

The mineral occurs intimately associated with amphibole, the finer needles of which tend to lie in the plane of cleavage of the clinochlore. The bastite-like mineral accompanying these groups is evidently derived from the amphibole.

Titanite is found in small, angular grains. *Picotite,* in minute grains, is especially abundant in the rock with much amphibole.

Magnetite, in a finely divided state, is disseminated through the rock, accompanying more especially the highly pleochroic serpentine. Higher powers show innumerable trichites and globulites, probably of the same mineral.

Chromic iron-ore may be represented by the dull, opaque masses already mentioned—these never show the forms of chromite; they are probably derived from pyroxene, olivine, or perhaps garnet.

[1] B. Lindemann, 'Petrographische Studien in der Umgebung von Sterzing in Tirol.' Neues Jahrb. Min., 1906, Beilage-Band xxii, pp. 454–554.

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Iron-pyrites is found in small quantity in the rock with much pyroxene.

A carbonate, probably *Magnesite*, without twin-lamellae, occurs frequently in both the rock-specimens.

Serpentine-minerals.—The ground-mass in which the above-mentioned minerals are embedded consists of serpentine in two forms: (1) a conspicuously pleochroic mineral, seen most frequently in the veinlets of the net-like structures, and never appearing as compact crystals; (2) a mineral almost colourless in thin sections, often filling the meshes with groups of parallel fibres resembling bastite, and more rarely simulating on a very minute scale the trellis-work figured by von Drasche. This latter form is held to be one of the varieties of serpentine to which the name antigorite has been given, and is here called the 'mineral *A*', the more pleochroic serpentine being called *S*.

A mineral to all appearance identical with *A* is well shown in the section of a rock-specimen from Sprechenstein near Sterzing, Tirol, belonging to my collection of 1905. This specimen furnished the material for the following description of the mineral *A*. The slide contains an abundance of lath-like forms like those represented in von Drasche's fig. 2, and also the pavement or mosaic-structure shown in the same author's fig. 3[1].

In the Sprechenstein rock the forms in the groups similar to those of von Drasche's fig. 3 show little or no cleavage, whilst with moderately high magnification a very perfect cleavage, like that of the micas, can be recognized in the lath-like forms.

In polarized light the laths present the appearance of twinning after the manner of clinochlore. Extinctions up to 3° have been measured. In convergent light the laths showing the most perfect cleavage give the interference-image of a positive bisectrix with a wide angle of the optic axes: this is probably the acute bisectrix. The negative bisectrix has not been observed.

Individuals showing little cleavage have been found giving the image of an optic axis. The dark bar of the hyperbola appears in this case to be only very slightly curved; the convexity seems to be towards the c bisectrix, again indicating a positive crystal with an axial angle approaching 90°.

The slide of the Sprechenstein rock is too thin to show the pleochroism, but pleochroic colours have been observed in the powdered mineral

[1] These forms are recognized by von Drasche (loc. cit.) to be sections respectively transverse and parallel to the cleavage of the antigorite.

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of this rock; bluish-green for vibrations parallel to the cleavage, and brownish-yellow for those transverse to the cleavage. The direction of the bluish-green absorption agrees with that given for antigorite by Hussak and by Weinschenk [1].

It appears from the above that the lath-like forms of the mineral *A* have the characters of individual crystals and not of fibrous aggregates. As regards optical properties, the mineral resembles the biotites, and perhaps some penninites in the optical orientation, the *a* bisectrix being nearly normal to the plane of cleavage. In the low index of refraction, the low double refraction, and the nature of the absorption (the greenish ray vibrating parallel to the cleavage) the mineral resembles the chlorites.

The optical scheme for the mineral *A* given in fig. 1 differs somewhat from that given by Hussak and by Weinschenk for antigorite (fig. 2). Hussak's observations were made on a mineral described as highly pleochroic with leek-green absorption parallel to the cleavage. Weinschenk's mineral was also distinctly pleochroic [2].

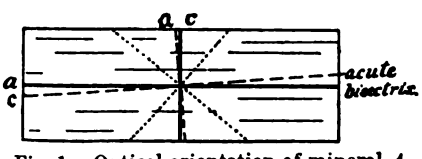

Fig. 1.—Optical orientation of mineral *A*.

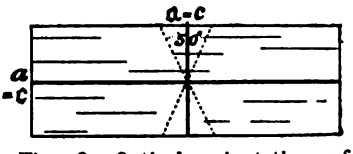

Fig. 2.—Optical orientation of antigorite, according to Hussak and Weinschenk.

The differences can perhaps be explained by supposing the last-named minerals to contain an isomorphous constituent richer in iron oxide, the presence of which determines a wandering of the optic axes towards the *c* axis.

[1] E. Weinschenk, 'Beiträge zur Petrographie der östlichen Centralalpen speciell des Gross-Venedigerstockes.' Abhandl. bayer. Akad. Wiss., 1895, vol. xviii, pp. 651–746. (See p. 661.)

[2] The antigorite of the Antigorio valley diverges in optical properties still more, though in the same direction, from the mineral *A*, the axial angle varying from 0° to 36°. (C. Klein, Sitzungsber. preuss. Akad. Wiss., 1894, p. 768.)

Tschermak gives 20° or more for the axial angle of the Sprechenstein mineral, but says (p. 255), apparently quoting Hussak, 'die kleinste Elasticitätsaxe ist senkrecht zur Spaltebene'—which is, perhaps, a clerical error. (G. Tschermak, 'Die Chloritgruppe.' Sitzungsber. Akad. Wiss. Wien, math.-nat. Classe, 1890, vol. xcix, Abth. I, pp. 174–267.)

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In the slides of the Tarnthaler rock the more pleochroic veinlets of the mineral *S* forming the 'network' of the serpentine ground-mass appear to have a slightly higher index of refraction. The polarization-tints are also higher than those of the fibrous mineral in the meshes.

The pleochroism is seen in the thinnest sections, the colours being about the same as in the nearly colourless mineral *A*. The strongest contrast of pleochroic tints is observed when the axis of the vein is respectively parallel and transverse to the principal section of the nicol, being bluish-green for the first and brownish-yellow for the second position. The extinctions also take place in these positions. The axis of greater elasticity is transverse to the axis of the veinlet, coinciding with the yellowish absorption.

The veinlets often show a median longitudinal suture as if they had grown symmetrically by accretion from the walls inwards after the manner frequent in mineral-veins. In polarized light there is often an appearance of fibrous structure, the threads being often at right angles to the walls but occasionally lying obliquely to the walls. There is no break of continuity at the curves of the veinlet. All these facts suggest that the veinlets are built up of ultra-microscopic crystal-elements placed with the axes of elasticity parallel and at right angles to the walls of the veinlets.

It does not appear that the visible fibres represent the ultimate structure of the veinlets of *S*. If it be assumed that these are composed of minute plates of a mica-like mineral with the cleavage planes parallel to the walls of the vein, the mineral will be found to agree in all important respects with the mineral *A*. On this assumption the mineral *S* would approximate closely to the antigorite of Hussak and to that of Weinschenk, both of which are distinctly pleochroic.

Bastite.—Numerous pseudomorphs measuring up to 4 mm. across show the schiller of bastite and are found to resist weathering better than the mass of the rock. On the plateau, where they form numerous prominences on the exposed surfaces, some of these pseudomorphs were seen to be coated with a film of a mineral with bright, silvery lustre.

Sections of these pseudomorphs transverse to the lamellae show, under the microscope, numerous very thin parallel streaks of a mineral with a higher index of refraction and much brighter polarization-tints than those of the antigorite. These streaks, often less than 1 μ and seldom more than 2 μ in thickness, are crowded together to the number of thirty-five or more to the millimetre. The interspaces are filled with

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the mineral *A*, usually in the bastite form. Veins of the mineral *A* are seen traversing the pseudomorphs in all directions, independently of the position of the streaks of the more refringent mineral.

The pseudomorphs, consisting mainly of the same material as the ground-mass of the rock, show no very distinct boundaries, especially when the striae are absent.

The mineral composing the striae, really sections of films, shows polarization-tints as high as those of the amphibole, and extinguishes when the striae make a high angle with the principal sections of the crossed nicols. The orientation of the mineral in the films is not known.

It is apparently this mineral which confers the power of resistance to weathering exhibited by these pseudomorphs. A single film cannot be the cause of the silvery reflexions. It is thought that the mineral *A* between the films has been gradually removed by atmospheric influences leading to an accumulation of films by the resulting collapse. The process would go on here with little interruption, as the site is rarely visited.

The bastite pseudomorphs are probably derived from aggregates of the nature of diallage consisting of two minerals in alternating lamellae.

Geologic relations.

A serpentine-rock with olivine has been reported by Rothpletz[1] from the Röckner, close to which is the site of the pyroxene-bearing serpentine here described. This intrusion may thus be compared with those of the Rettenkopf and Todtenköpfe in the Hohe Tauern, described by Becke[2] and Weinschenk[3], and that of the Geisspfad in the Swiss Alps reported by Preiswerk[4], in both of which pyroxene-bearing rocks follow on those rich in olivine.

The serpentine of the Röckner and of the other Tarnthaler summits is found in close proximity to rock-masses showing the typical foliation of the phyllites and containing talc and other magnesian minerals.

The phyllites occupy the crest of the ridge over the chain of frozen

[1] A. Rothpletz, loc. cit.

[2] F. Becke, 'Olivinfels und Antigorit-Serpentin aus dem Stubachthal (Hohe Tauern).' Min. Petr. Mitt. (Tschermak), 1894, vol. xiv, pp. 271–6.

[3] E. Weinschenk, loc. cit.

[4] H. Preiswerk, 'Der Serpentin am Geisspfad (Oberwallis).' Eclogae geologicae Helvetiae, 1901, vol. vii, pp. 123–5.

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lakes in the high valley which drains to north and west into the Navis-Thal. They show vertical, plane-parallel joints, which cross the foliation and the axis of the ridge at right angles. The joints are not carried downward into the younger underlying rocks, which include Triassic limestones and the dolomite-breccia of Rothpletz.

The present position of the rocks can only be accounted for by movements of faulting, folding, and overthrust, according to F. E. Suess [1]. According to P. Termier, these rocks form part of a long, recumbent fold [2].

The geologic relations of the Tarnthaler mass show that the intrusion of the serpentines was completed before the commencement of the movements which brought the rocks into their present position. The last great movement was not concerned in producing the foliation of the crystalline schists.

The same relation between serpentine and phyllite is seen to hold at Matrei-am-Brenner and at Pfons, where Blaas traced a complete transition from the ophicalcites and serpentines with little or no foliation to the highly foliated schists.

The masses of the Röckner and of Matrei-am-Brenner are igneous intrusions, the borders of which have been foliated in the same degree as the crystalline schists, whilst the cores have been preserved almost intact. The intrusion of these masses commenced at a period immediately preceding the close of the processes which brought about the foliation of the crystalline schists. The intrusions were continuous and contemporaneous, or nearly so, for margin and core. Before the cores of the masses could be influenced the conditions and activities determining foliation ceased to be effective, and have not since been renewed in this portion of the crust.

[1] F. E. Suess, 'Das Gebiet der Triasfalten im Nordosten der Brennerlinie.' Jahrb. geol. Reichsanstalt, Wien, 1894, vol. xliv, pp. 589–668.

[2] P. Termier, 'Les Nappes des Alpes orientales et la synthèse des Alpes.' Bull. Soc. géol. de France, 1904, sér. 4, vol. iii, pp. 711–65.

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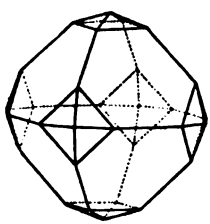
Isomorphism as illustrated by certain varieties of Magnetite.

By Professor B. J. Harrington, M.A., LL.D., F.C.S.

[Communicated by L. Fletcher, F.R.S., and read January 29, 1907.]

SOME years ago the writer received from St. Joseph du Lac in the County of Two Mountains, province of Quebec, Canada, a few small specimens of a black mineral which was identified as magnetite. Later, a more careful inspection of the fragments, which weighed from ten to fifteen grams each, showed that some of them were portions of crystals made up of an unusual combination, the octahedron {111} and a trapezohedron {311}. Further, chemical analysis showed that the composition was specially interesting, the mineral being titaniferous and containing, besides 3·24 per cent. of magnesia, a larger proportion of manganese than had been observed in the case of any magnetite previously examined. The crystals displayed no cleavage or parting, but a conchoidal to subconchoidal fracture. Hardness, about 6. Specific gravity (determined with the pycnometer), 4·918. Lustre, metallic and splendent: colour and streak, black. Strongly magnetic. The results of the chemical analysis were as follows:—



Magnetite from St. Joseph du Lac, Quebec: forms {111}, {311}.

		Atomic ratios of metals.	Atomic ratios of oxygen.
Ferric oxide ...	59·71	0·746	1·119
Titanium dioxide ...	5·32	0·066	0·132
Alumina ...	0·62	0·012	0·018
Ferrous oxide ...	22·70	0·315	0·315
Manganous oxide ...	8·46	0·119	0·119
Magnesia ...	8·24	0·081	0·081
Silica	0·16	—	—
	100·21	1·339	1·784

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Then dividing respectively by 3 and 4 we get $\frac{1{\cdot}339}{3} = 0{\cdot}445$ and $\frac{1{\cdot}784}{4} = 0{\cdot}443$, the correct ratio for magnetite and other members of the spinel group. It is, of course, unlikely that the titanium exists in the mineral as dioxide; and if it be calculated as sesquioxide and the difference in the oxygen transferred to the iron the analysis becomes:—

		Atomic ratios of oxygen.	
Ferric oxide	65·01	... 1·219	
Titanium sesquioxide ...	4·79	... 0·120	1·357
Alumina	0·62	... 0·018	
Ferrous oxide	17·98	... 0·249	
Manganous oxide ...	8·46	... 0·119	0·449
Magnesia	3·24	... 0·081	
Silica	0·16		
	100·21		

Here the oxygen-ratio for protoxides and sesquioxides ($RO : R_2O_3$) is 0·449 : 1·357, or almost exactly 1 : 3 (1 : 3·022).

Another view with regard to the condition of the titanium in such minerals is that of Mosander, Knop, and others, viz. that it is present as $FeO.TiO_2$ or $FeTiO_3$, which replaces Fe_2O_3 isomorphously. Calculated on this basis the analysis would be:—

		Atomic ratios of oxygen.	
Fe_2O_3 ...	59·71	... 1·119	
$FeTiO_3$ ...	10·11	... 0 199	1·336
Al_2O_3 ...	0·62	... 0·018	
FeO ...	17·91	... 0·249	
MnO ...	8·46	... 0·119	0·449
MgO ...	3·24	... 0·081	
SiO_2 ...	0·16		
	100·21		

Here the ratio for RO to R_2O_3 (including $FeTiO_3$ with the latter) is also practically 1 : 3 (1 : 2·975). Knop[1], who made a study of octahedrons of titaniferous magnetite yielding on analysis 24·95 per cent. of TiO_2, favoured the last view as to constitution; for here if the titanium were calculated as Ti_2O_3 the ratio of $RO : R_2O_3$ was 1 : 1·165, while if FeTiO

[1] A. Knop, 'Ueber titansäurehaltigen Magneteisenstein.' Annalen der Chemie (Liebig), 1862, vol. cxv[illegible] 53.

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were regarded as replacing Fe_2O_3 the ratio became a normal spinel ratio. In all such cases, however, the question of the distribution of the oxygen is largely speculative, and the really significant ratio is that between the metals and oxygen as a whole. There is no probability whatever that in the case of the St. Joseph du Lac crystals the titanium is present in the form of intermixed rutile. Owing to the exceptionally large proportion of manganese the mineral may be regarded as intermediate between magnetite proper and jacobsite.

The form {311}, which is rare in magnetite, occurs also in spinel and other members of the group, including gahnite, franklinite, and chromite. It is very well developed in some of the spinel crystals from Amity and Monroe in New York State.

Since writing the above, the writer has paid a hurried visit to St. Joseph du Lac in the hope of discovering the exact locality from which the magnetite crystals were obtained. The person who had found them having died some time before, no definite information as to the exact spot was available, but some of the farmers of the district had long known of a massive magnetic ore occurring in connexion with crystalline limestone on Lot 71 of the Parish of Oka. This spot was visited and specimens of the ore obtained. They are black in colour and streak, less brilliant in lustre than the crystals described above and not quite so strongly magnetic. The specific gravity of a fragment was found to be 4·61, and a partial analysis proved that the mineral in addition to being titaniferous also contains considerable quantities of manganese and magnesia, the percentages of these three constituents being as follows:—

Titanium dioxide	...	6·94
Manganous oxide	...	8·90
Magnesia ...	...	5·58

The composition, in a general way, therefore, is similar to that of the crystals, and it is not unlikely that a more careful examination of the region would result in the discovery of the original locality.

The late Professor Penfield of Yale having called the writer's attention to the fact that magnetite crystals from Magnet Cove, Arkansas, also exhibited the combination {111}, {311} (with rhombic-dodecahedral faces in some cases), specimens from this locality, which have been for many years in the mineral collection of McGill University, have been submitted to chemical analysis in order to ascertain whether similarity of form was accompanied by closely related composition. The results, however, show that in the latter respect they differ decidedly from the

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Canadian mineral. The Magnet Cove crystals lack the freshness and brilliancy of those from St. Joseph du Lac. Their hardness is about 6, and specific gravity 4·558. Lustre, metallic. Colour black and streak blackish-brown. Attracted by the magnet, though not so strongly as in the case of the mineral already described. The fine powder was not completely soluble in hydrochloric acid at ordinary pressures, but it dissolved completely on heating with hydrochloric acid in a sealed tube for several hours at a temperature of 150° C. The ferrous oxide was determined by decomposing in this way and titrating with potassium dichromate. The mineral was also completely decomposed by fusion with sodium disulphate. Quantitative analysis gave the following results:—

		Atomic ratios of metals.	Atomic ratios of oxygen.
Ferric oxide ...	59·01	0·739	1·106
Titanium dioxide ...	2·40	0·030	0·060
Alumina	10·37	0·203	0·304
Ferrous oxide ...	16·82	0·234	0·233
Manganous oxide ...	2·10	0·030	0·029
Magnesia	9·47	0·237	0·236
	100·17	1·473	1·968

Here, again, the ratio for metals to oxygen is the normal one, as will be seen by dividing respectively by 3 and 4: $\frac{1\cdot473}{3} = 0\cdot491$, and $\frac{1\cdot968}{4} = 0\cdot492$.

If, as in the last case, the titanium be calculated as Ti_2O_3 the analysis becomes:—

		Atomic ratios of oxygen.	
Ferric oxide ...	61·41	1·151	
Titanium sesquioxide	2·16	0·045	1·500
Alumina	10·37	0·304	
Ferrous oxide ...	14·66	0·204	
Manganous oxide ...	2·10	0·029	0·469
Magnesia	9·47	0·236	
	100·17		

Here the ratio for $RO : R_2O_3$ is 1 : 3·19 instead of 1 : 3, possibly indicating alteration and change in the distribution of oxygen between the ferrous and ferric iron. The alumina was determined by difference

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in the usual way and not directly. The large proportion of this constituent and of the magnesia indicate a mineral intermediate in composition between magnetite and spinel[1].

A third specimen of crystallized magnetite has also been examined, in order to ascertain whether its composition was exceptional. It came from Digby, Annapolis County, Nova Scotia, where it is said to occur in veins in the trap-rocks of the region. The crystals are about three-quarters of an inch in diameter and composed of two forms {111} and {110}. In no case has the trapezohedron been observed. The specific gravity was found to be 5·067, and chemical analysis gave the following results:—

		Atomic ratios of metals.	Atomic ratios of oxygen.
Ferric oxide ...	70·64	0·883	1·324
Titanium dioxide ...	0·24	0·003	0·006
Ferrous oxide ...	26·13	0·363	0·363
Manganous oxide ...	trace	—	—
Magnesia	2·97	0·074	0·074
Silica	0·03	—	—
	100·01	1·323	1·767

Dividing by 3 and 4, we have $\frac{1\cdot323}{3} = 0\cdot441$ and $\frac{1\cdot767}{4} = 0\cdot441$, exactly the normal ratio for magnetite. As in the former cases, no lime was found, but magnesia was again present, no doubt replacing ferrous oxide.

The analyses given in this paper do not establish any definite relationship between crystalline form and chemical composition in magnetite, but are offered as a contribution to the study of isomorphism as occurring in this important species.

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Many years ago Professor G. A. Koenig examined nodular masses of magnetite from Magnet Cove and found them to be titaniferous and also to contain a little vanadium ($V_2O_3 = 0\cdot17$). It was the writer's intention to examine the crystals for vanadium, but owing to want of time this has not been done. For Professor Koenig's analysis see Proc. Acad. Nat. Sci. Philadelphia, 1877, p. 293.

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Baddeleyite from Ceylon.

By G. S. Blake, A.R.S.M., B.Sc., F.C.S.
Assistant in the Scientific and Technical Department of the Imperial Institute.

And G. F. Herbert Smith, M.A., D.Sc., F.G.S.
Assistant in the Mineral Department of the British Museum.

[Read March 19, 1907.]

DURING recent years a systematic survey of the mineral resources of Ceylon has been in progress, in connexion with which a large number of specimens have been sent to the Imperial Institute for examination. In 1905 several cases containing coarse gravel from the streams of the gem-district of Balangoda were received. The constituent minerals were mainly zircon, tourmaline, corundum, spinel, ilmenite, together with small quantities of geikielite[1], fergusonite, and other rare-earth minerals. Last summer during the examination of these gravels one of the authors found three black crystals with unusually brilliant faces. The apparently monoclinic form and the general physical characters at once suggested the crystallized native zirconia, baddeleyite, and this conjecture was confirmed by the goniometrical measurements and the chemical analysis.

It is of interest to note that prior to this discovery there is no record of a specimen of this mineral being found in the island since Mr. L. Fletcher[2] first determined, fifteen years ago, not only the crystallographical but also the chemical properties of this species by means of an investigation of a single rough crystal, now exhibited in the Mineral Gallery of the British Museum. This crystal was included among a lot of specimens of heavy minerals which had been collected by Mr. Joseph Baddeley at Rakwana, Ceylon, and brought by him to England. Mr. Fletcher detected the crystal when picking out specimens of the then new mineral, geikielite,

[1] T. Crook and B. M. Jones, 'Geikielite and the ferro-magnesian titanates.' Min. Mag., 1906, vol. xiv, pp. 160–6.

[2] Nature, 1892, vol. xlvi, p. 420. L. Fletcher, 'On baddeleyite (native zirconia), a new mineral, from Rakwana, Ceylon.' Min. Mag., 1893, vol. x, pp. 148–60.

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which Mr. Baddeley had courteously offered to the Museum. Crystals of baddeleyite have been found in abundance by Dr. E. Hussak in the magnetite deposits at Jacupiranga, São Paulo, Brazil, and his description[1] of them was published almost simultaneously with Mr. Fletcher's paper.

(a) *Crystallographical Characters.*

Of the three crystals mentioned above, one was broken at both ends and displayed the prism-zone only; it was used for the chemical analysis Each of the remaining crystals possesses faces at one end. One (fig. 1) is a twin of the common type with *a* (100) as the plane of twinning; of the two individuals, one has the forms *a* {100}, *b* {010}, *m* {110}, *d* {021}, *r* {$\bar{1}$01}, *a* {$\bar{2}$01}, and *n* {$\bar{1}$11}, and the other *a* {100}, *b* {010}, *c* {001}, *m* {110}, *d* {021}, and *n* {$\bar{1}$11}. Contiguous faces of the form *d* {021} on the two individuals meet in a re-entrant angle. The crystal measures approximately 5 mm. in length, 8 mm. in width, and 4 mm. in thickness,

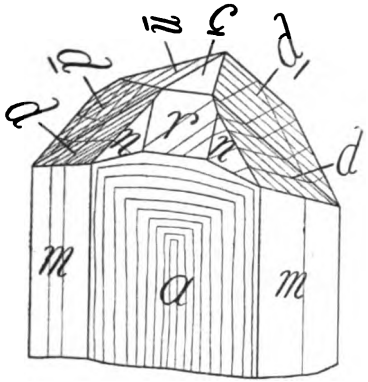

Fig. 1.

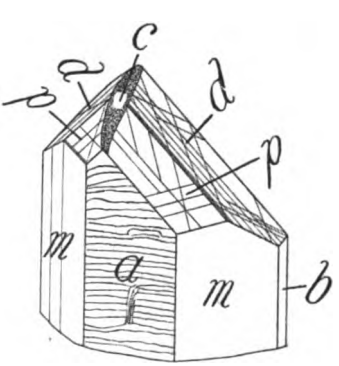

Fig. 2.

Baddeleyite from Ceylon (twinned and simple crystals).

and it weighs 0·695 gram. The other (fig. 2) is a simple crystal and untwinned. It is remarkable how rare such crystals are; out of some

[1] E. Hussak, 'Über Brazilit.' Neues Jahrb. Min., 1892, vol. ii, pp. 141-5; 'Ueber den Baddeleyit (syn. Brazilit) von der Eisenmine Jacupiranga in São Paulo.' Min. Petr. Mitt. (Tschermak), 1895, vol. xiv, pp. 395-406. The name 'brazilite' was withdrawn by Dr. Hussak.

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hundreds of crystals isolated by him, Dr. Hussak[1] found only three which were not twinned, and the crystal described by Mr. Fletcher also is twinned. The simple crystal displays the forms $a\{100\}$, $b\{010\}$, $c\{001\}$, $m\{110\}$, $g\{210\}$, $d\{021\}$, $t\{101\}$, and $p\{221\}$. It measures approximately 9 mm. in length, 7 mm. in width, and 3 mm. in thickness, and weighs 0·775 gram. As shown in the drawing, the top is slightly broken. Both crystals are striated in such a way as to indicate polysynthetic twinning with respect to both a (100) and m (110), a character remarked by Dr. Hussak on the Brazilian crystals and fully described by him. Both are black in colour, and sub-metallic and opaque in appearance. In thin splinters, however, the substance is seen to be transparent and yellowish in colour.

The forms observed, eleven in number, and their characters are as follows:—

$a = \{100\}$ large; striated irregularly: good reflexions.

$b = \{010\}$ small.

$c = \{001\}$ not large; slightly uneven.

$m = \{110\}$ large; striated parallel to the prism-edge: reflexions good.

$g = \{210\}$ large on the simple crystal (at the back as shown in fig. 2), otherwise small; sometimes forms the sides of pittings on a (100): reflexions poor.

$t = \{101\}$ small.

$r = \{\bar{1}01\}$ small: only once observed.

$o = \{\bar{2}01\}$ minute.

$d = \{021\}$ large; striated: reflexions good.

$p = \{221\}$ large; striated: reflexions good.

$n = \{\bar{1}11\}$ not large; striated: reflexions good.

The form $g = \{210\}$ has not been recorded before.

The notation and parameters of Dr. Hussak have been adopted in this paper. Mr. Fletcher selected a slightly different parametral plane; his (hkl) is equivalent to $(h.k.2l)$ of Dr. Hussak.

Both crystals were measured on the three-circle goniometer in the British Museum from the faces of the form $a\{100\}$, which despite the markings on them invariably gave well-defined reflexions, as origin, and the measurements with the corresponding calculated values are given in the following table:—

[1] Min. Petr. Mitt. (Tschermak), 1894, vol. xiv, p. 399.

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TABLE I.

Measurements from a = (100).

Form.	Calculated Values.		Observed Values.			
			Twinned Crystal.		Simple Crystal.	
	Azimuth.	Distance.	Azimuth.	Distance.	Azimuth.	Distance.
c 001	90° 0′*	80° 32′	90° 0′	80° 32′	89° 56′	80° 23′
t 101	,, ,,	55 24½	...	...	,, ,,	55 10
r 10$\bar{1}$	,, ,,	−70 23½	90 0	−70 37		
a 20$\bar{1}$	,, ,,	−47 54	,, ,,	−47 54		
n 11$\bar{1}$	62 56	−72 24	62 57	−72 14		
			62 53	−72 9		
			62 55	−72 2		
d 021	44 28*	83 21	44 17	83 31	44 14	83 18
			44 26	83 27	44 33	83 16
			44 27	83 21		
			44 22	83 13		
p 221	,, ,,	49 41½	...	...	44 14	49 44
					44 33	49 35
b 010	0 0	90 0*	0 0	89 59	0 0	89 53
			,, ,,	89 43		
m 110	...	44 20*	,, ,,	44 27	,, ,,	44 19
			,, ,,	44 14	,, ,,	44 26
			,, ,,	44 12	,, ,,	44 24
			,, ,,	44 24	,, ,,	44 14
g 210	...	26 2	...	...	,, ,,	26 0
						26 3
						26 2

The angles from which the calculations have been made are indicated by asterisks.

The calculated coordinates of the observed forms with respect to the face of symmetry *b* = (010) as origin are tabulated below :—

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TABLE II.

Coordinates from b = (010).

$a:b:c = 0{\cdot}9905:1:0{\cdot}5110$; $\beta = 99°\,28'$.

Form.		Azimuth.	Distance.
r	101	−70° 23½′	90° 0′
n	111	,, ,,	64 18
c	001	80 32	90 0
d	021	,, ,,	44 46½
t	101	55 24½	90 0
p	221	39 30½	56 58½
a	100	0 0	90 0
g	210	,, ,,	63 58
m	110	,, ,,	45 40
b	010	,, ,,	0 0

The crystals are unusually large, and their faces unusually plane for this mineral; Dr. Hussak, indeed, found crystals measuring as much as 5 mm., but owing to the distortion of the faces they were quite useless for purposes of measurement, and Mr. Fletcher's crystal also gave very ill-defined reflexions. The measured values in the prism-zone agree closely with those recorded by Dr. Hussak; but in the zone of symmetry [*ac*] there is an appreciable difference between the values observed on these crystals and those noted by Dr. Hussak. The following table compares the observed values in the two cases:—

	Hussak.	Smith.
am = (100):(110)	44° 17½′ . . .	44° 20′
ac = (100):(001)	81 14½ . . .	80 32
ar = (100):(10$\bar{1}$)	69 41 . . .	70 37
at = (100):(101)	55 51 . . .	55 24½

Dr. Hussak found as the limiting values for the angle *ac*=(100):(001) 80° 56½′ and 81° 42′, so that the measurements in the present case lie well outside this range.

On the other hand, the values calculated from the fundamental angles selected in this paper accord in certain cases better with Dr. Hussak's observations than do his own calculated values; thus:—

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	Hussak. Observed.	Hussak. Calculated.	Smith. Calculated.
$an = (100):(11\bar{1})$ . . .	72° 16′	71° 45½′	72° 24′
$ap = (100):(221)$ . . .	49 40½	50 41	49 41½
$ad = (100):(021)$ . . .	83 28	83 51	83 21

There is a noticeable variation in the specific gravity, which is comparable with, though not so great as, that observed in the case of zircon. Mr. Fletcher gives 6·025 as the value for the crystal examined by him, whereas Dr. Hussak obtained 5·5 for the Brazilian crystals. In the case of the present crystals, the specific gravities of the crystal used in the analysis and of the twinned crystal are 5·72 and 5·73 respectively, while for the simple crystal it is as much as 5·82.

(b) *Chemical Examination.*

The crystal which was utilized for the determination of the chemical composition weighed 0·6418 gram, and had a specific gravity of 5·72. It was ground to a powder and fused for several hours with potassium hydrogen sulphate. The resulting mass was dissolved in water, and the silica in the small amount of insoluble residue determined. The hydrochloric acid solution of the bases, freed from potassium sulphate, was treated with ammonium oxalate, and it was found that the thorium and cerium metals were absent. The ammonium oxalate was removed, and sodium thiosulphate was added to the nearly neutral solution. The amount of iron in the filtrate was determined. The precipitate, which consisted presumably of zirconium thiosulphate, was converted into hydroxide and weighed as oxide. The precipitate was re-dissolved and tested for uranium and titanium, but a trace of the latter element only was detected.

The following are the results of the analysis (G. S. B.):—

Zirconia, ZrO_2	98·90
Ferric oxide, Fe_2O_3 } Ferrous oxide, FeO } . . .	0·82
Lime, CaO	0·06
Silica, SiO_2	0·19
Loss on ignition.	0·28
	100·25

The following are the characteristic reactions of the principal element in the mineral :—

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(*a*) From a solution, ammonium oxalate precipitates the oxalate, which is readily soluble in excess of the reagent, either acid or neutral;

(*b*) Sodium thiosulphate precipitates it from neutral solutions;

(*c*) The neutral sulphate forms an insoluble double salt with potassium sulphate.

These reactions suffice to group the element with thorium, zirconium and titanium. The proof that it is actually zirconium was sought for by the preparation of the fluoride. The oxide obtained from the analysis was dissolved in hydrofluoric acid and the solution slowly evaporated in a covered platinum crucible with the formation of colourless, transparent crystals, which were dried first on filter-paper, and then for two days *in vacuo* over calcium chloride. The crystals have the triclinic symmetry described by Marignac[1], but were not well developed. It was found that 0·3000 gram of this salt yielded 0·1638 gram of the oxide. If the composition be assumed to be $ZrF_4.3H_2O$, the element would have an atomic weight of 91, which is so near that determined for zirconium, viz. 90, as to justify the inference that the oxide contained this element alone of the group given above.

The chemical analysis of the mineral has been further confirmed by a spectroscopic examination, which was undertaken by Mr. A. Fowler at the Royal College of Science, London. The arc-spectrum was photographed with an instrument of high dispersion, and a comparison with the tables of Exner and Haschek in the region of 4367 to 4689 shows all the lines of zirconium recorded by those observers with the exception of one at 4408·54. The only additional strong line in this part is at wave-length 4602·73. The spectrum, however, was found to be identical with that given by a portion of a crystal of common zircon, except that the baddeleyite showed a slight trace of manganese in addition to iron.

[1] Annales chim. phys., 1860, sér. 3, vol. lx, pp. 266–7.

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On the occurrence of silver ore in the Perran mine, Perran Uthnoe, Cornwall.

By Francis H. Butler, M.A., A.R.S.M., L.S.A. (Lond.).

[Read March 19, 1907.]

THE deposit known as the Wheal Sedgman lode is inclined to the west a few degrees from the vertical, and runs in a direction about 10° W. of N. (magnetic) through the parish of Perran Uthnoe, near Marazion, Cornwall. In its course seawards from the approximately E. and W. lode formerly worked in the Great Wheal Neptune mine, it traverses the North and South Trebarvah tin and copper lodes. It is crossed by the shore-line on Perran Sands, about 500 yards to the west of Trevean cliff. Between that spot and Cuddan Point, to the S.E., where it is again laid bare, it has been superficially removed by marine denudation. The numerous N. and S. diabase dikes of the district show in places much disseminated pyrrhotite, and one of them runs nearly parallel to the east side, or foot wall, of the Sedgman lode. The bed-rock of the district is a pyritous bluish killas, which, where it forms the 'country', or walls adjoining the lode, is finely laminated and very variable in hardness, being occasionally represented at its junction with the lode by a clay. In breadth the Sedgman lode varies from 6 feet to 18 inches. In the northern part it consists of a series of roughly parallel bands of quartz and chalybite. The quartz is crystalline and of a pure white, and carries a little bright mispickel, with blende, pyrite, and chalcopyrite. The chalybite is externally pale buff and internally nearly white, and contains some cavities enlarged by aqueous erosion without oxidation and others lined with lenticular crystals of the same mineral. This spathic and wide portion of the lode is practically non-argentiferous, the chalybite containing only half an ounce of silver to the ton: the invariable experience, as Mr. G. D. McGrigor informs me, is that where there is chalybite, there is no silver ore. The Sedgman lode within 200 yards to the south of the Great Wheal Neptune deposit consists of more or less argentiferous, friable, and ochreous or harder, chocolate-coloured, and quartzose

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limonite with parallel seams of ferruginous, highly compact, splintery quartz, which passes into crystalline quartz only in the less argentiferous parts of the lode. This quartz (locally called the 'cab-course') is found to be best developed where the limonite is richest in cerargyrite, the prevalent silver ore, although this mineral has only once been observed implanted on hard quartz.

The amount of silver obtained in driving on the course of the lode to a depth as yet not exceeding 18 fathoms has varied from over 11,000 to as little as 2 ounces to the ton of limonitic ore. In proportion as the workings have been carried south, the richest ore has been discovered progressively deeper; i. e. the line of most complete silverization, or secondary enrichment, of the original lode corresponds roughly to that of the contour or shoreward trend of the overlying land. This fact illustrates the remark of the late J. G. Goodchild[1] that, speaking generally, one may say that around certain points where the occurrence of ore in any given set of veins reaches a maximum elevation above the sea, the upper limit of occurrence of the ore in the several veins falls successively to lower and lower levels in proportion to their distance from those highest points. He further makes the interesting observation, in dealing with the North of England lead-veins, that 'the parallelism between the deep-seated phenomena and the surface features points to former variation in the downward increment of temperature connected with the shape of the ground when the veins were formed'.

In the Sedgman lode it is the lower and more friable, or gossany, limonite that has proved the more argentiferous. Another noteworthy fact is that the deposition of hornsilver has been greatest at irregular intervals along oblique lines having a sharp slope seawards. In consequence, within a few feet in depth, the richer ore may appear on opposite sides of a narrow shaft.

Besides cerargyrite, no other silver ores have so far (March 1907) been found in the Perran mine, save a little galena, a few ounces of massive argentite, forming a nucleus of the ordinary lode-stuff, and a small specimen of wire-like native metal. The cerargyrite occurs either intimately mixed with the limonite and crystallized in usually much distorted small cubes and cubo-octahedra upon its free surfaces or in malleable and sectile masses from an ounce or two to several pounds in weight. Of numerous analysed examples of the cerargyrite not one has yielded more than traces of bromine.

[1] J. G. Goodchild, 'Some observations upon the mode of occurrence and the genesis of metalliferous deposits.' Proc. Geol. Assoc., 1889, vol. xi, pp. 45–69.

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Visible cassiterite has been come upon twice in the working of the lode, and the refuse from the dressing of the ore has been found to contain about 0·1 per cent. of 'black tin'. There is evidence also that the ore contains some 5 grains of gold to the ton.

History of the Lode.—On examination of the lode and of hand-specimens therefrom it becomes patent that, as with Cornish mineral-veins in general, siliceous solutions were largely concerned both in the production of the original Perran deposit, and in bringing about modifications therein. What such solutions can effect is well exemplified in various districts in the west of England, e.g., in the production of the greisen of the Bunney mine and of the Rock Hill clay-pit, in St. Austell parish, of Kit Hill, and of Cligga Head. There broad or narrow courses of granite in the direction of planes of fracture have been first kaolinized and then deprived of their kaolin and furnished with fresh quartz, varying quantities of secondary mica, commonly much schorl, cassiterite crystals, and occasionally fluor. In the northern part of the Sedgman lode, the alternation of bands of chalybite and quartz, the presence of slickensides one behind another, and the inclusion in the chalybite of fragments of brecciated killas testify that the original fissure was enlarged and gradually filled during a succession of earth-movements. The normal tints of the chalybite and quartz here found and the unmodified condition of their disseminated mineral contents indicate that any lode-water that may have reached them after deposition was free from oxidizing agents. The blueness of the neighbouring killas points to the same conclusion.

The fissure having been occupied by chalybite and quartz, the chalybite along a considerable extent of the lode, but not in the northern part, was subjected to the action of a siliceous solution that contained a limited supply of available oxygen, but was rich in silver and in chlorine, the last-named element possibly owing its presence to the access of sea-water to abyssal regions. It is interesting to note in this connexion that the multitudinous fluid-containing vesicles of the quartz of a fluor-kaolin-rock in a quarry between Nanpean and Trethosa, in Cornwall, near the Mineral Railway, mostly contain each a cube of salt besides the usual bubble. The effect of the second aqueous invasion of the Sedgman lode was largely to decarbonate, hydrate, and oxidize the chalybite in its southern portion, forming limonite, to add considerably to the quartz already there existing, and to cause the irregular deposition of silver chloride in cavities and on free surfaces. Why the lode was not similarly attacked in its whole length might be as difficult

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to explain as the sporadic kaolinization of granite that is observable in some of the St. Austell clay-pits.

Since, in the alteration of chalybite to limonite, four molecules of carbon dioxide became nascent for every molecule of oxygen taken out of solution, the vein-water was rendered a powerful solvent of the residual chalybite. That it had been deprived of any available oxygen it may originally have contained is evidenced by the lack of adventitious superficial coloration of the quartz in some of the cavities in limonite from the interior of which chalybite has been removed, and also by the fresh and unaltered condition of the surface of masses of chalybite still in part occupying other of those cavities. The ultimate oxidation of ferrous carbonate dissolved out of the lode may account for much of the ferruginous staining and cementation of the rubbly and brecciated material at its out-crop.

The cassiterite of the lode is possibly of late origin in its history, and may have been derived from the source of supply of the E. and W. lodes of the district of Perran.

For free access to the Perran mine and its products during the preparation of this paper, I am indebted to the courtesy of the managing owner, Mr. G. D. McGrigor.

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Communications from the Oxford Mineralogical Laboratory. No. IX.

On Hamlinite from the Binnenthal, Switzerland.

By H. L. Bowman, M.A., F.C.S.

Demonstrator of Mineralogy in the University of Oxford.

[Read June 11, 1907.]

In a paper read before this Society in 1904 [1], dealing with a number of new minerals from the Binnenthal dolomite, Mr. R. H. Solly described under the name of bowmanite some small, honey-yellow crystals belonging to the rhombohedral system and forming either hexagonal plates or combinations of rhombohedron and basal planes of octahedral habit. Mr. Solly afterwards handed over the small amount of available material to me for further examination.

In density, hardness, cleavage, habit, and sign of birefringence, the crystals were found to resemble hamlinite, the phosphate of aluminium and strontium, described by W. E. Hidden and S. L. Penfield [2] from the herderite locality at Stoneham, Maine, and later by Penfield [3] from Oxford Co., Maine. They differed from this mineral, however, in being pseudo-hexagonal—the hexagonal plates showing a division into biaxial sectors, while hamlinite from Stoneham was stated to give a perfectly normal uniaxial interference-figure.

The quantity of material (amounting only to a few milligrams) was too small to admit of an analysis being made, but from qualitative tests of a few minute grains, the mineral appeared to be a phosphate of lime and alumina, with small amounts of iron, water, and possibly magnesia. In the light of later work, however, it seems probable that the calcium and magnesium found here may have been derived from traces of dolomite.

Since that time Mr. Solly has kindly obtained for me some more specimens, found in 1905 and 1906, so that I have been enabled to make a more detailed study of the mineral and to collect sufficient pure material for some quantitative experiments, which have resulted in its identification with hamlinite.

[1] Min. Mag., 1905, vol. xiv, pp. 72–82.
[2] Amer. Journ. Sci., 1890, ser. 3, vol. xxxix, p. 511.
[3] Ibid., 1897, ser. 4, vol. iv, p. 313.

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Occurrence.—The crystals, which rarely exceed 1 mm. in diameter (the largest I have seen being a hexagonal plate 1·3 mm. in diameter and 0·7 mm. in thickness), and are usually much smaller, occur on the surface of cracks and cavities in the white dolomite, associated with hyalophane, colourless crystals of barytes, and modified rhombohedra of dolomite, often lining the surface; sometimes also small, colourless crystals of quartz and minute, black crystals of rutile. The dolomite is generally rich in brown flakes of biotite and often contains granular iron-pyrites, while crystals of blende and iron-pyrites are also present on some specimens. In one case, some crystals of hamlinite are scattered over the surface of a rough prism of rathite. Perfect, symmetrically-developed crystals of hamlinite frequently occur embedded loosely in a white, powdery material, from which they are easily freed by rubbing between the fingers.

Crystalline Form.—The crystals are very simple, the only forms observed being $c\{111\}$ and $r\{100\}$, of varying relative sizes, sometimes with minute faces of $f\{11\bar{1}\}$ on the edges or corners.

Two types of habit may be distinguished, viz. (1) flat hexagonal plates with modified edges, sometimes aggregated in rosettes, and (2) stouter crystals showing the unit rhombohedron and resembling either octahedra or cubes according to the size of the faces of $c\{111\}$.

The crystals are generally very symmetrically developed, but the faces are almost always uneven and do not yield good reflexions of the signal. Measurements between faces giving only single images, on four tabular crystals, gave values varying between 53° 44′ and 55° 49′ for the obtuse angle *cr*, and between 123° 44′ and 125° 52′ for the corresponding acute angle, the means being 54° 58½′ and 125° 4½′ respectively.

This agrees well with the measured angle found by Penfield (about 55°), though the angle adopted by him (calculated from $rr = 87° 2'$) was $cr = 52° 40'$.

There is a good cleavage parallel to $c\{111\}$.

The colour varies considerably, crystals ranging from nearly colourless to reddish-brown. The flat, hexagonal crystals are characteristically pale in colour with a brown spot in the centre.

Optical Properties.—Some of the smaller, tabular crystals appear isotropic under the microscope (except at the extreme edges), and in convergent light show a normal uniaxial interference-figure, with moderately weak, positive birefringence; but larger ones always show a division into six, more or less regular, triangular, biaxial sectors, which possess weak birefringence compensated by a quartz-wedge inserted

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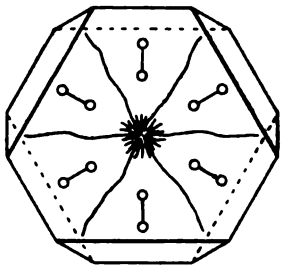
radially. The sectors are separated by wavy, dark lines along which, and also at the centre of the crystal, the interference-figure is uniaxial (see fig.). The sectors extinguish together in pairs, roughly parallel to the corresponding edge of the hexagon, and each gives a positive biaxial figure with the axial plane nearly perpendicular to that edge. The axial angle (2E) varies from 0° up to about 50°.



Optical orientation of hamlinite from the Binnenthal.

Thus the crystals are pseudohexagonal, the variation in the optical properties being due to the overlapping of twin-lamellae parallel to the cleavage, as in the case of the micas, chlorites, &c.

The angles between the edges of the hexagonal plates do not appear to be exactly 60° (values were observed varying between 58½° and 62°), while the extinction-directions in the sectors are frequently not quite parallel to the edges, but deviate sometimes as much as 5° from this position, and on adjacent sectors include angles of 57°–63°.

The symmetry of the component crystals may thus be lower than that of the orthorhombic system, but the observations are not sufficiently concordant to warrant any definite conclusions being drawn from them.

The darker (reddish-brown) crystals are slightly pleochroic, when viewed along the plane of cleavage, vibrations parallel to the cleavage (ω) being reddish-brown, while those perpendicular to it (ϵ) are yellow.

Specific Gravity.—The density of twelve selected crystals, apparently quite pure, was determined by means of methylene iodide and a Westphal's balance, and found to vary from 3·219 up to 3·266. That of hamlinite from Stoneham is given as 3·228, while the crystals from Oxford Co. analysed by Penfield varied between 3·159 and 3·283.

The hardness is about 4 or rather more.

Chemical Composition.—The mineral is insoluble in hydrochloric acid, as sharp crystals, after boiling with the acid, showed under the microscope no sign of being attacked and were unchanged in colour; they are, however, readily decomposed on fusion with alkaline carbonates.

The results of a preliminary examination, made on 0·0659 gram of slightly impure material, which proved to contain about 6 per cent. of silica (probably from admixed hyalophane), are given in column I of the table. The powder (dried at 98° C.) was ignited in a platinum crucible to constant weight. It was then fused with alkaline carbonates, dissolved in nitric acid, and the phosphoric acid precipitated (after

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separation of the silica) by ammonium molybdate and weighed as magnesium pyrophosphate. The estimation of alumina and the other constituents could not be carried out owing to the presence of impurities in the ammonium molybdate used.

An attempt was then made on the main portion of pure material (0·1127 gram) to determine the water directly by Penfield's method (column II). The powder was heated to low redness in a boat of platinum-

	I.	II.	III.	IV.	Penfield.
P_2O_5	24·2	26·1	...	...	30·31
Al_2O_3	...	35·6	...	...	32·65
SrO	...	...	19·2	20·5	19·29
BaO	...	...	0·2	0·1	4·08
H_2O	...	[12·4]	...	...	12·48
F	...	...	...	...	2·04
Loss on ignition	15·6	[12·9]	15·6	16·0	
K_2O	...	...	...	0·4	
SiO_2	5·9	3·8	0·9	0·7	
Insoluble in HCl	...	...	2·1	...	

foil, and the water found amounted to 12·4 per cent., while the loss of weight of the boat was 12·9 per cent. The water was markedly acid, and probably contained a little hydrofluoric acid, as the glass was slightly attacked and the outside of the boat showed a slight deposit of silica. The cause of the low value here obtained is probably an insufficiently high temperature, as it was afterwards found that intense ignition was required to drive off the last portions—whether of water or fluorine. Owing to the small amount of material available, no attempt has been made to determine the proportions of these two constituents.

The silica and phosphoric acid were determined as before. The figure for alumina is probably not very reliable, owing to the difficulty of separating it from the large amount of molybdic acid present.

As the numbers so far obtained approximated to those given by Penfield for hamlinite from Oxford Co., Maine (quoted in the last column), I made a direct test for barium and strontium, without previous separation of phosphoric acid.

Columns III and IV give the results of two determinations made with 0·0340 and 0·0568 gram respectively of a fresh sample of material. They may not therefore be quite comparable with the previous determinations. The loss of weight was determined in a platinum crucible and

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was found to be complete only after long and intense ignition. The powder, which was found to be slowly soluble after ignition, was dissolved in hydrochloric acid, the silica separated by evaporation in the usual way, and barium and strontium then precipitated as sulphates. On applying Fresenius's method of separation by double precipitation with ammonium chromate, as used by Penfield for hamlinite, barium was found to be present only in traces.

Considering the small amount of material used, the agreement with Penfield's numbers for hamlinite, when taken in connexion with the similarity in crystalline characters, appears to be sufficiently close to prove the identity of the two minerals. The difference in the optical characters is only such as might be expected in a pseudosymmetric substance, and may possibly be connected with the difference in the mode of occurrence,—the hamlinite from Maine being found in granitic rock, associated with herderite and bertrandite.

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A (fourth) list of new mineral names[1].

By L. J. Spencer, M.A., F.G.S.

Assistant in the Mineral Department of the British Museum.

Aegirine-hedenbergite. F. von Wolff, 1904. Centralblatt Min., 1904, p. 214 (Aegirin-Hedenbergit). A monoclinic pyroxene intermediate in composition between aegirite and hedenbergite. H. Rosenbusch (Mikroskopische Physiographie d. Mineralien, 4th edit., 1905, vol. i, part 2, p. 218) prefers the form Hedenbergit-Ägirin.

Analcidite. C. Hintze, 1897. Handbuch d. Mineralogie, vol. ii. p. 1714 (Analcidit). The more correct derivation of analcite, from ἄναλκις, ἀνάλκιδος, weak.

Ansilit. Zeits. Kryst. Min., 1906, vol. xli, p. 184. Error for ancylite, owing to the name having been transliterated into Russian and back again.

Antiperthite. F. E. Suess, 1905. Jahrb. geol. Reichsanst. Wien, vol. liv, pp. 419, 425 (Antiperthite, *pl.*). Regular intergrowths of two felspars in which orthoclase is the enclosed mineral and plagioclase the host; being the reverse of the case which holds in microperthite.

Argentoalgodonite. G. A. Koenig, 1903. Proc. Amer. Phil. Soc., vol. xlii, p. 229; Zeits. Kryst. Min., 1904, vol. xxxviii, p. 537. An artificially prepared copper arsenide containing some silver $(Cu,Ag)_6As$.

Argentodomeykite. G. A. Koenig, 1903. Proc. Amer. Phil. Soc., vol. xlii, p. 229; Zeits. Kryst. Min., 1904, vol. xxxviii, p. 537. An artificially prepared copper arsenide containing some silver $(Cu,Ag)_3As$.

Astrolite. R. Reinisch, 1904. Centralblatt Min., 1904, p. 108 (Astrolith). Small, greenish-yellow spheres with radially fibrous structure, which occur embedded in fragments of carbonaceous quartz-schist, limestone, and shale in a basalt-tuff at Neumark, Saxon Vogtland. $(Al,Fe)_2Fe''(Na,K)_3(SiO_3)_8 . H_2O$. Named from ἄστρον, stars, and λίθος, stone; known locally as 'Sternle'.

[1] Previous lists are given at the ends of vols. xi, xii, and xiii of this Magazine (1897, 1900, 1903).

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Babylonian quartz. (P. Groth, Mineraliensammlung, Strassburg, 1878, p. 100 (Babylonquarz). Century Dictionary, New York, 1889.) Synonym of babel-quartz.

Baryta-orthoclase. J. E. Strandmark, 1904. Geol. Fören. Förh. Stockholm, 1903, vol. xxv, p. 289; 1904, vol. xxvi, p. 97. Celsian, $BaAl_2Si_2O_8$, is shown to be monoclinic and to form a series of mixed crystals with orthoclase. Celsian ranges in composition from Ce to Ce_1Or_2, the other members of the series being classed as baryta-orthoclases (baryt-kalifältspater); those having the composition Ce_1Or_2—Ce_1Or_6 are referred to hyalophane, whilst those with still less barium (Ce_1Or_6—Or) are called barium-bearing orthoclases (barythaltiga kalifältspater). J. P. Iddings (Rock Minerals, New York, 1906, p. 283) refers to minerals of the last of these divisions as barium-orthoclase.

Beckelite. J. Morozewicz, 1904. Rozpr. Akad. Kraków, Ser. A, vol. xliv, p. 216; Bull. Intern. Acad. Sci. Cracovie, 1905, année 1904, p. 485 (beckelicie, Beckelith, béckélite); Min. Petr. Mitt. (Tschermak), 1905, vol. xxiv, p. 120. Wax-yellow, octahedral or rhombic-dodecahedral crystals resembling pyrochlore in appearance and physical characters. Occurs in a dyke modification of elaeolite-syenite near Mariupol on the Sea of Azov, Russia. Calcium cero-lanthano-didymo-silicate, $Ca_3(Ce,La,Di,Y)_4(Si,Zr)_3O_{15}$. Named after Professor Friedrich Becke, of Vienna.

Bellite. W. F. Petterd, 1905. Rep. Secr. Mines, Tasmania, for 1904, p. 83. 'Chromo-arsenate of lead' occurring as velvety tufts of bright red or yellow, hexagonal needles or as powdery encrustations at Magnet, Tasmania. [The analysis suggests a mixture of crocoite, mimetite, and quartz.] Named after W. R. Bell, a prospector in Tasmania. The name bellite has long been in use for an explosive.

Beryllium-humite. H. Rosenbusch, 1905. Mikroskopische Physiographie d. Mineralien, 4th edit., vol. i, part 2, p. 193 (Berylliumhumite, *pl.*). Humite containing a small amount of beryllium (BeO, 1 per cent.) and no fluorine, $Mg_5(MgOH)_2(SiO_4)_3$. Analysed by P. Jannasch and J. Locke (1894), and described by R. W. Schäfer (1895) from the serpentine of the Allalin district, Wallis, Switzerland.

Blanfordite. L. L. Fermor, 1906. Trans. Mining and Geol. Inst. India, vol. i, p. 78. A monoclinic pyroxene containing some sodium, manganese, and iron, occurring with manganese ores in the Central Provinces, India. The strong pleochroism (rose-pink to sky-blue) is

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a prominent character. Named after the late Dr. William Thomas Blanford (1832–1905).

Blomstrandine. W. C. Brögger, 1906. Videnskabs-Selsk. Skrifter, Kristiania, 1906, No. 6, p. 98 (Blomstrandin). A titano-niobate of yttrium-earths, thorium, uranium, &c., occurring at Hitterö, Arendal, and other localities in Norway, as large orthorhombic crystals, which had previously (W. C. Brögger, 1879) been referred to aeschynite. Named after the late Professor Christian Wilhelm Blomstrand (1826–97), of Lund, Sweden, whose analyses showed it to be distinct from aeschynite. It is dimorphous with polycrase and isomorphous with priorite (q.v.). Not to be confused with the blomstrandite of G. Lindström (1874), which is a hydrated titano-niobate and -tantalate of uranium, &c.

Borax, octahedral. *See* 'Octahedral borax'.

Bowmanite. R. H. Solly, 1904. Nature, vol. lxxi, p. 118; Min. Mag., 1905, vol. xiv, p. 80. Small, honey-yellow, rhombohedral crystals from the white, crystalline dolomite of the Binnenthal in Switzerland. Named after Herbert Lister Bowman, of Oxford, and proved by him (Min. Mag., 1907, vol. xiv, p. 389) to be identical with hamlinite.

Californite. G. F. Kunz, 1903. Amer. Journ. Sci., ser. 4, vol. xvi, p. 397. F. W. Clarke and G. Steiger, Bull. U.S. Geol. Survey, 1905, no. 262, p. 72. Massive, green idocrase occurring as large masses in California. It resembles jade in appearance, and is used as an ornamental stone.

Carbapatite. P. N. Tschirwinsky, 1906. Annu. Géol. Min. Russie. vol. viii, p. 251 (карбапатитъ), p. 256 (Carbapatit). A name later withdrawn (Centralblatt Min., 1907, p. 283) in favour of podolite (q.v.).

Carborundum. E. G. Acheson, 1893. Journ. Franklin Inst. Philadelphia, vol. cxxxvi, p. 194. Silicide of carbon, CSi, formed artificially as brilliant, rhombohedral crystals and extensively used as an abrasive agent. Named from carbon and corundum, because, before it had been analysed, it was thought to be a compound of carbon and alumina. More recently (1904) the same substance has been isolated from a meteoric iron and named moissanite (q.v.).

Cerepidote. H. Rosenbusch, 1905. Mikroskopische Physiographie d. Mineralien, 4th edit., vol. i, part 2, p. 286 (Cerepidot). Synonym of allanite. So named because it is a member of the epidote group containing cerium.

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Chlormanganokalite. H. J. Johnston-Lavis, 1906. Nature, vol. lxxiv, p. 104. A. Lacroix, Compt. Rend. Acad. Sci. Paris, 1906, cxlii, p. 1251; H. J. Johnston-Lavis and L. J. Spencer, Nature, 1907, vol. lxxvi, p. 215. Chloride of manganese and potassium, $MnCl_2 . 4KCl$, found as yellow, deliquescent, rhombohedral crystals in blocks ejected from Mount Vesuvius.

Chlornatrokalite. H. J. Johnston-Lavis, 1906. Nature, vol. lxxiv, p. 174. Potassium and sodium chloride, 6KCl.NaCl, found as cubic crystals with chlormanganokalite in blocks ejected from Mount Vesuvius.

[Specimens of 'chlornatrokalite' sent by Dr. Johnston-Lavis to the British Museum consist of cubes of sylvite and of halite in association.—L. J. S.]

Chocolite. J. Garland, 1894. Trans. Inst. Mining and Metallurgy, 1893–4, vol. ii, pp. 128, 224. A chocolate-coloured nickel-ore from New Caledonia; a hydrated silicate of iron, nickel, and magnesium, related to garnierite.

Coronadite. W. Lindgren and W. F. Hillebrand, 1904. Amer. Journ. Sci., ser. 4, vol. xviii, p. 448; Bull. U.S. Geol. Survey, 1905, no. 262, p. 42; Profess. Paper U.S. Geol. Survey, 1905, no. 43, p. 103. A black, metallic mineral with finely fibrous structure; not unlike psilomelane in appearance. Manganite of lead and manganese, $(Pb,Mn)O . 3MnO_2$. Occurs in fairly large amount in the Coronado vein, Clifton-Morenci district, Arizona. Named after the Spanish explorer, Francisco Vasquez de Coronado, who visited the region in 1540.

Crenite. D. A. Wells, 1852. Proc. Amer. Assoc. Adv. Sci., vol. vi, p. 230. Stalactitic calcite coloured yellow by organic matter, which was identified with crenic acid or crenate of calcium.

[J. Fromme (Jahresber. Ver. Naturwiss. Braunschweig, 1897, vol. x, p. 104) found 0·231 per cent. of apocrenic acid in chestnut-brown, translucent crystals of calcite from the Harz.]

Cryolithionite. N. V. Ussing, 1904. Overs. K. Danske Videnskab. Selsk. Forhandl., 1904, p. 3. Large, colourless rhombic-dodecahedra found in the cryolite of Greenland. $Li_3Na_3Al_2F_{12}$. So named because of its relation to cryolite and the large amount of lithium (5·35 per cent.) it contains.

Dachiardite. G. D'Achiardi, 1906. *See* Zeolite mimetica.

Davidite. D. Mawson, 1906. Trans. R. Soc. South Australia, vol. xxx, p. 191. An incompletely described mineral [possibly identical

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with ilmenite] from South Australia. Named after Professor T. W. Edgeworth David, of Sydney University.

Denhardtite. H. Potonié, 1905. Monatsber. Deutsch. geol. Ges., 1905, p. 259 (Denhardtit). A pale yellow, waxy hydrocarbon similar to pyropissite. It is derived from plants and forms a stratum in loam in British East Africa. Named after the brothers Clemens and Gustav Denhardt, by whom it was collected in 1878.

Doughtyite. W. P. Headden, 1905. Proc. Colorado Sci. Soc., vol. viii, p. 66. Hydrated basic aluminium sulphate, $Al_2(SO_4)_3 . 5Al_2(OH)_6 . 21H_2O$, formed abundantly as a white precipitate by the interaction of the waters (an alkaline water and one containing aluminium sulphate) of the Doughty Springs, in Delta Co., Colorado. Named after Mr. Doughty, the owner of the springs.

Dubuissonite. C. Baret, 1904. Bull. Soc. Sci. Nat. de l'ouest de la France, Nantes, ser. 2, vol. iv, p. 141. A pink clay from near Nantes, analysed by A. Damour in 1885 and placed by A. Lacroix (Minéralogie de la France, 1895, vol. i, p. 483) under montmorillonite; it differs from this, however, in its resistance to acids and in its fusibility. Named after Mr. Dubuisson, mineralogist and founder of the museum at Nantes.

Ebelmenite. (Collection de Minéralogie du Muséum d'Histoire Naturelle, Paris, Guide du Visiteur, 2nd edit., 1900, p. 29.) A variety of psilomelane containing potassium. Named after Jacques Joseph Ebelmen (1814–52), who analysed a specimen in 1841.

Erikite. O. B. Boeggild, 1903. Contributions to Mineralogy, Min. Geol. Mus. Univ. Copenhagen, no. 2, p. 93; Meddelelser om Grønland, 1904, vol. xxvi, p. 93. Brown and opaque, orthorhombic crystals from the nephelite-syenite near Julianehaab in Greenland, when examined in thin section under the microscope, were seen to consist of an intergrowth of two substances, of which the predominant one (erikite) is yellow, strongly refracting and birefringent, whilst the other is probably hydronephelite. An analysis of this mixture corresponds with the formula $8SiO_2 . 4P_2O_5 . 4(Ce,La,Di)_2O_3 . 3Al_2O_3 . CaO . 3Na_2O . 11H_2O$. Named after Erik the Red, who discovered Greenland in A.D. 986.

Ferrinatrite. R. Scharizer, 1905. Zeits. Kryst. Min., vol. xli, p. 209 (Ferrinatrit). To replace the name ferronatrite (J. B. Mackintosh, 1889), since the mineral to which it is applied is a hydrated sodium ferric (not ferrous) sulphate.

Giorgiosite. A. Lacroix, 1905. Compt. Rend. Acad. Sci. Paris,

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vol. cxl, p. 1310; Bull. Soc. franç. Min., vol. xxviii, p. 198. A basic magnesium carbonate occurring as a white powder on lava erupted from Santorin in 1866. Under the microscope it is seen to consist of minute, birefringent spherules, and to have the same characters as the artificial compound $4MgCO_3 . Mg(OH)_2 . 4H_2O$. Named from Giorgios, one of the cones formed during the eruption of 1866.

Glendonite. T. W. E. David and T. G. Taylor, 1905. Records Geol. Survey New South Wales, vol. viii, p. 161. Large pseudomorphs of granular calcite, probably after glauberite, found in abundance at Glendon on the Hunter River and other localities in New South Wales. They were described by J. D. Dana in 1849, and are similar to thinolite and pseudogaylussite.

Gorceixite. E. Hussak, 1906. Min. Petr. Mitt. (Tschermak), vol. xxv, p. 388 (Gorceixit). Hydrated barium aluminium phosphate, $BaO . 2Al_2O_3 . P_2O_5 . 5H_2O$, occurring as brown pebbles ('favas'), with a compact, jaspery structure, in the diamond-bearing sands of Brazil. It is optically uniaxial, and belongs to the hamlinite group of minerals. Named after Professor Henri Gorceix, formerly director of the School of Mines at Ouro Preto, Brazil.

Greenalite. C. K. Leith, 1903. Monogr. U.S. Geol. Survey, vol. xliii, pp. 14, 101, 239. A hydrous silicate of iron occurring in the form of green granules and closely resembling glauconite, from which it differs in containing no potassium. The composition varies somewhat; one analysis gives the formula $Fe_2'''(Fe,Mg)_3(SiO_4)_3 . 3H_2O$. Occurs abundantly as a constituent of sedimentary rocks in the Mesabi iron-bearing district of Minnesota.

Greenite. John Ruskin, 1884. Catalogue of a series of specimens in the British Museum (Natural History) illustrative of the more common forms of native silica. Orpington, Kent (G. Allen), 1884, p. 28. The English equivalent of chlorite. 'Chlorite, which ought to be more simply termed "Greenite" or "Greeny", is a combination of . . .'

Harttite. E. Hussak, 1906. Min. Petr. Mitt. (Tschermak), vol. xxv, p. 341 (Harttit). Hydrated strontium aluminium sulphato-phosphate, $SrO . 2Al_2O_3 . P_2O_5 . SO_3 . 5H_2O$, near svanbergite in composition. It is found as flesh-red pebbles ('favas') in the diamond-bearing sands of Brazil. The crystalline structure is rhombohedral. Named in memory of Charles Frederick Hartt (1840–78), the first director of the Geological Survey of Brazil.

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Hedenbergit-Ägirin. *See* Aegirine-hedenbergite.

Hibschite. F. Cornu, 1905. Min. Petr. Mitt. (Tschermak), vol. xxiv, p. 327; 1906, vol. xxv, p. 249 (Hibschit). Minute, octahedral, optically isotropic crystals of contact-metamorphic origin, occurring in enclosures of chalk-marl in phonolite at Aussig, Bohemia. It usually forms a colourless layer around a nucleus of green titaniferous melanite. The chemical composition, $H_4CaAl_2Si_2O_{10}$, is the same as of the orthorhombic lawsonite. Named after Professor Josef Emanuel Hibsch, of Tetschen, Bohemia.

The same mineral also occurs in enclosures of limestone in basalt at Aubenas, Ardèche, France, and was described by A. Lacroix in 1893 as colourless garnet with a core of brown melanite.

Hollandite. L. L. Fermor, 1906. Trans. Mining and Geol. Inst. India, vol. i, p. 76. A crystallized manganate of barium, manganese, and ferric iron, $m(Ba,Mn)_2MnO_5 + nFe_4(MnO_5)_3$. From Central India. Named after Thomas Henry Holland, Director of the Geological Survey of India.

Hutchinsonite. R. H. Solly, 1904. Min. Mag., 1905, vol. xiv, p. 72. (A preliminary account of the unnamed mineral appeared in Nature, 1903, vol. lxix, p. 142, and the name (Hutchinsonit) was first printed in Min. Petr. Mitt. (Tschermak), 1904, vol. xxiii, p. 551.) G. T. Prior, Nature, 1905, vol. lxxi, p. 534. G. F. H. Smith and G. T. Prior, Min. Mag., 1907, vol. xiv, p. 284. Minute, red, orthorhombic crystals found in the white, crystalline dolomite of the Binnenthal, Switzerland. An analysis made on a small amount of material suggests the formula $(Tl,Cu,Ag)_2S \cdot As_2S_3 + PbS \cdot As_2S_3$; thallium is present to the extent of about 20 per cent. Named after Dr. Arthur Hutchinson, of Cambridge.

Ilmenitglimmer. H. Rosenbusch, 1905. Mikroskopische Physiographie d. Mineralien, 4th edit., vol. i, part 2, p. 81. The same as Titaneisenglimmer (q.v.).

Irvingite. S. Weidman, 1907. Amer. Journ. Sci., ser. 4, vol. xxiii, p. 451. A variety of lithia-mica differing somewhat from other varieties in chemical composition. Occurs with marignacite (q. v.) in pegmatite-veins near Wausau, Wisconsin. Named after Roland Duer Irving (1847–88), formerly of the Geological Survey of Wisconsin.

Isorthose. L. Duparc, 1904. Compt. Rend. Acad. Sci. Paris, vol. cxxxviii, p. 715. A variety of orthoclase (French, orthose) differing from ordinary orthoclase in optical orientation: the acute bisectrix of the optic axes is positive in sign and is perpendicular to the plane

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of symmetry. It is met with in granite from the northern Urals and in the protogine of Mont Blanc.

Janosite. H. Böckh and K. Emszt, 1905, Földtani Közlöny, Budapest, vol. xxxv, pp. 76, 139; ibid., vol. xxxvi, pp. 186, 228, 404, 455 (Jánosit). Described as an orthorhombic, hydrated normal ferric sulphate, $Fe_2O_3.3SO_3.9H_2O$, dimorphous with coquimbite; it occurs as a greenish-yellow, powdery efflorescence at Vashegy, Comitat Gömör, Hungary. Named after Dr. János [=John] Böckh, Director of the Geological Survey of Hungary.

Proved by E. Weinschenk (ibid., 1906, vol. xxxvi, pp. 182, 224, 289, 359) and Z. Toborffy (ibid., 1907, vol. xxxvii, pp. 122, 173; Zeits. Kryst. Min., 1907, vol. xliii, p. 369) to be identical with copiapite, $2Fe_2O_3 . 5SO_3 . 18H_2O$, which is orthorhombic and not monoclinic.

Jentschite. Min. Petr. Mitt. (Tschermak), 1904, vol. xxiii, p. 551; Min. Mag., 1905, vol. xiv, p. 80 footnote. Synonym of lengenbachite (q.v.). Named after Franz Jentsch, mineral dealer of Binn, Switzerland. Not to be confused with the jenzschite of J. D. Dana, 1868.

Johnsonite. H. D. Richmond and H. Off, 1892. Chemiker-Zeitung, Jahrg. xvi, pp. 567, 648 (Johnsonit); Chem. News, vol. lxv, p. 257. A fibrous alum, containing the supposed new element masrium, found in Egypt by S. E. Johnson Pasha. The mineral was immediately afterwards re-named masrite (see first list, Min. Mag., vol. xi, p. 331).

Justite. Min. Petr. Mitt. (Tschermak), 1904, vol. xxiii, p. 97 (Justit); the name also appears on dealers' labels. Synonym of koenenite (see third list, Min. Mag., vol. xiii, p. 369). Named from the Justus I salt-mine in Hanover, where the mineral was found.

Kassiterolamprit. A. Frenzel. C. Hintze, Handbuch d. Mineralogie, 1904, vol. i, p. 1191 footnote. Thought to be a new mineral from Bolivia, but afterwards identified with stannite.

Katharite. W. Ainsworth, 1834. An account of the caves of Ballybunian, County of Kerry: with some mineralogical details. Dublin, 1834, pp. 83, 85. Synonym of alunogen. Named katherite or katharite 'from καθαρος [i. e. κάθαρός], impermixtus, simplex; in allusion to the absence of potash', it being hydrous aluminium sulphate and thus more simple in composition than alum.

Kertschenite. S. P. Popoff, 1906. Centralblatt Min., 1906, p. 113 (Kertschenit). Hydrated phosphate of iron with small amounts of manganese and magnesium, $(Fe,Mn,Mg)O . Fe_2O_3 . P_2O_5 . 7H_2O$. It occurs

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as radially fibrous aggregates of dark-green, flattened crystals in the limonitic iron-ores of the Kerch (German, Kertsch) peninsula, Crimea.

Kleinite. A. Sachs, 1905. Sitzungsber. Akad. Wiss. Berlin, 1905, p. 1091; Centralblatt Min., 1906, p. 200 (Kleinit). An oxychloride of mercury, $Hg_4Cl_2O_3$, containing small amounts of nitrogen and sulphate. It occurs as sulphur-yellow, hexagonal crystals in the mercury-mines at Terlingua, Texas. Named after Professor Carl Klein (1842–1907), of Berlin.

Kutnohorite. A. Bukovský, 1901. [Anz. III Congr. böhm. Naturf. u. Aerzte, Prag, 1901, p. 293; Programm d. Oberrealschule in Kuttenberg, 1902]; Neues Jahrb. Min., 1903, vol. ii, Ref. p. –338– (Kutnohorit). A rhombohedral carbonate with the atomic ratios Ca : Mn : Fe : Mg = 7 : 5 : 1 : 2, occurring as reddish-white cleavage-masses at Kutná Hora (German, Kuttenberg), Bohemia.

Landerite. M. M. Villada, 1891. La Naturaleza, México, ser. 2, vol. i, p. 502 (Landerita). A beautiful, pink grossularite occurring as large rhombic-dodecahedra embedded in white marble at Xalostoc, Morelos, Mexico. It was analysed by A. Damour in 1871 and by Carlos F. de Landero in 1891, after whom it is named. Also called rosolite and xalostocite (q.v.).

Landevanite. Comte de Limur. A. Lacroix, Minéralogie de la France, 1895, vol. i, p. 484. 'Under the name of landevanite, M. de Limur has distributed to his correspondents a rose-coloured clay coming from Landevan in Morbihan and resulting from the decomposition of a pegmatite rich in albite.' It is placed by Lacroix under montmorillonite.

Lengenbachite. R. H. Solly, 1904. Nature, vol. lxxi, p. 118; Min. Mag., 1905, vol. xiv, p. 78. Thin, blade-shaped crystals, probably anorthic, occurring in the white, crystalline dolomite of the Lengenbach, Binnenthal, Switzerland. Analysis by A. Hutchinson (Min. Mag., 1907, vol. xiv, p. 204) gives the formula $Pb_6(Ag,Cu)_2As_4S_{13}$. *See* Jentschite.

Lepidolamprite or Schuppenglanz. A. Breithaupt. C. Hintze, Handbuch d. Mineralogie, 1904, vol. i, p. 1198 footnote (Lepidolamprit). A specimen of franckeite (A. W. Stelzner, 1893) in the Freiberg collection was so labelled by Breithaupt in the first half of the nineteenth century.

Magnesium-diopside. H. Rosenbusch, 1905. Mikroskopische Physiographie d. Mineralien, 4th edit., vol. i, part 2, pp. 200, 206 (Magnesiumdiopsid). A monoclinic pyroxene near to diopside, but containing only 8–9 per cent. CaO.

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Marignacite. S. Weidman and V. Lenher, 1907. Amer. Journ. Sci., ser. 4, vol. xxiii, p. 287. A variety of pyrochlore occurring as brown octahedra in pegmatite at Wausau, Wisconsin. It differs from other members of the pyrochlore group in containing rather more cerium and yttrium with less calcium and iron, and in the presence of a small amount of silica. Named after Jean Charles Galissard de Marignac (1817–94).

Marrite. R. H. Solly, 1904. Nature, vol. lxxi, p. 118; Min. Mag., 1905–6, vol. xiv, pp. 76, 188. Small, steel-grey crystals with brilliant metallic lustre found in the white, crystalline dolomite of the Binnenthal, Switzerland. They are monoclinic with a rich development of faces; their chemical composition is not known. Named after Dr. John Edward Marr, of Cambridge.

Metaautunite. P. Gaubert, 1904. Bull. Soc. franç. Min., xxvii, p. 224 (Métaautunite). The same as Metakalkuranit (F. Rinne, 1901; third list, Min. Mag., xiii, p. 371).

Metaboracite. E. S. Fedorov, 1892. Zeits. Kryst. Min., vol. xx, p. 74. The names metaboracite, metaleucite, and metaperovskite (Metaboracit, Metaleucit, Metaperowskit) are applied to those dimorphous forms possessing higher symmetry met with at ordinary temperatures, whilst the names boracite, leucite, and perovskite respectively, are restricted to the cubic, optically isotropic modifications of the same substances which are stable only above certain temperatures.

Metachalcophyllite. P. Gaubert, 1904. Bull. Soc. franç. Min., vol. xxvii, p. 224 (Métachalcophyllite). Following F. Rinne (1901), this name is given to chalcophyllite which has been partly dehydrated by heating artificially until only the water of constitution remains; the loss of water is accompanied by changes in the optical characters.

Metaleucite. E. S. Fedorov, 1892. *See* Metaboracite.

Metanhydrite. E. Sommerfeldt, 1907. Neues Jahrb. Min., vol. i, p. 140 (Metanhydrit). A modification of calcium sulphate which in external form appears to be isomorphous with barytes, though in physical characters (sp. gr. and cleavage) it is identical with anhydrite. The crystals examined were prepared artificially: the same substance probably occurs as a volcanic product at Santorin.

Metaperovskite. E. S. Fedorov, 1892. *See* Metaboracite.

Metauranocircite. P. Gaubert, 1904. Bull. Soc. franç. Min., vol. xxvii, p. 226 (Métauranocircite). *See* Metachalcophyllite.

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Micaultlite. Comte de Limur, 1888. Catalogue raisonné des minéraux du Morbihan. Vannes, 1888, p. 38. An earthy, brick-red decomposition product of rutile, which is suggested may be an aluminous hydrorutile. Presumably named after Victor Micault, of Paris.

Minette. A mining term applied to oolitic brown-iron-ores (limonite) of Lorraine and Luxemburg. A diminutive of the French *mine*, ore, in allusion to the low content of metal in the ore.

Moissanite. G. F. Kunz, 1905. Centralblatt Min., 1905, p. 154; Amer. Journ. Sci., ser. 4, vol. xix, p. 396. Silicide of carbon, CSi, identical with the artificial product known as carborundum (q. v.), found by H. Moissan (Compt. Rend. Acad. Sci. Paris, 1904, vol. cxxxix, p. 778; 1905, vol. cxl, p. 405) as small, green, hexagonal plates in the meteoric iron of Cañon Diablo, Arizona. Named after Professor Henri Moissan (1852–1907).

Moravite. F. Kretschmer, 1906. Centralblatt Min., 1906, p. 293 (Moravit). A finely scaly chloritic mineral, of the leptochlorite group, occurring abundantly as iron-black masses with sub-metallic lustre in association with iron-ores at Gobitschau in Moravia. It resembles thuringite in appearance, but differs chemically from this, the formula being $H_4(Al,Fe)_4(Fe,Mg)_3Si_7O_{24}$. Named from the locality.

Morencite. W. Lindgren and W. F. Hillebrand, 1904. Amer. Journ. Sci., ser. 4, vol. xviii, p. 455; Bull. U.S. Geol. Survey, 1905, no. 262, p. 49; Profess. Paper U.S. Geol. Survey, 1905, no. 43, p. 115. A brownish-yellow mineral occurring in finely fibrous seams, the minute fibres having straight extinction. Hydrated ferric silicate with some magnesia, lime, &c., and a little alumina; $H_{22}R_2''Fe_6'''(SiO_4)_{11}$. Occurs in calcareous shale at Morenci, Arizona, and is probably an alteration product of some contact-metamorphic mineral.

Naegite. T. Wada, 1904. Minerals of Japan. Tōkyō, p. 49 (Naëgite). A tetragonal mineral occurring as small, rather indistinct crystals with angles near those of zircon. Described as a silicate of uranium, thorium, &c., and considered to be isomorphous with zircon; in a later analysis (Beiträge zur Mineralogie von Japan, 1906, no. 2, p. 23) zirconium figures largely. [Further investigation will probably prove its identity with zircon.] Found in alluvial tin-washings at Naëgi, near Takayama, Prov. Mino, Japan.

Nemaphyllite. F. Focke, 1902. Min. Petr. Mitt. (Tschermak), vol. xxi, p. 323 (Nemaphyllit). A chlorite-like mineral occurring as

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greenish scales with a fibrous structure: it has the composition of serpentine ($H_4Mg_3Si_2O_9$), containing also 2·11 per. cent. Na_2O. It is from the Zillerthal, Tyrol, where it sometimes forms regular intergrowths with dolomite. Named from *νῆμα*, a thread, and *φύλλον*, a leaf.

Nepouite. E. Glasser, 1906. Compt. Rend. Acad. Sci. Paris, vol. cxliii, p. 1173; Bull. Soc. franç. Min., 1907, vol. xxx, p. 17 (Népouite). A hydrated silicate of nickel (NiO,18·1—50·7 per cent.) and magnesium (MgO,8·0—30·0 per cent.) with the formula $3(Ni,Mg)O \cdot 2SiO_2 \cdot 2H_2O$, occurring as a finely crystalline, bright green to pale yellowish-green powder in niccoliferous peridotite at Népoui in New Caledonia. It differs from connarite, garnierite, &c., and in its optical characters it resembles the chlorites.

N'hangellite. (L. A. Boodle, Bull. Roy. Botanic Gardens, Kew, 1907, p. 145; Sir Boverton Redwood, ibid., p. 151.) An elastic bitumen derived from a gelatinous alga, and resembling coorongite; from the neighbourhood of Lake N'hangella in Portuguese East Africa.

Nuissierite. The same as nussierite (G. Barruel, 1836). A calciferous mimetite from the Nuissière lead-mine near Chenelette, dep. Rhône, France. The new spelling (nuissiérite) is given by A. Des Cloizeaux, Manuel de Minéralogie, 1893, vol. ii, p. 519.

'Octahedral borax.' The conditions necessary for the formation of the artificial salt long known as 'octahedral borax' (sodium borate, $Na_2B_4O_7 \cdot 5H_2O$, crystallizing in rhombohedral forms *r c* with the appearance of regular octahedra) have been investigated by J. H. van 't Hoff and W. C. Blasdale (Sitzungsber. Akad. Wiss. Berlin, 1905, p. 1086), who point out that this substance was observed by E. Bechi in 1854 as an incrustation at the Tuscan lagoons.

Oehrnite. E. S. Fedorov, 1905. Gornyi Zhurnal, St. Petersburg, year lxxxi, vol. iii, p. 264 (эрнить, Oehrnit). A rock-forming mineral from the Caucasus resembling diallage in appearance: it has three rectangular cleavages, but is shown by its optical characters to be monoclinic. The formula is given as $6(Mg,Fe,Ca)O \cdot 6SiO_2 \cdot H_2O$, but the analysis shows also Al_2O_3, 6·74 per cent. Named after A. G. Ern, a Russian mining engineer.

Osannite. C. Hlawatsch, 1906. Festschrift Harry Rosenbusch, Stuttgart, 1906, p. 76 (Osannit). Those soda-amphiboles, intermediate between riebeckite and arfvedsonite, in which the optic axial plane is perpendicular to the plane of symmetry and the acute, negative bisectrix

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nearly coincides with the vertical prism-axis. A constituent of amphibole-gneiss at Cevadaes, Portugal. Named after Professor Alfred Osann, of Freiberg in Baden.

Otavite. O. Schneider, 1906. Centralblatt Min., 1906, p. 389 (Otavit). A basic carbonate of cadmium (Cd, 61·5 per cent.) occurring as minute, curved rhombohedra and forming white to reddish crystalline crusts on copper-ores at Otavi in German South-West Africa.

Palaeoleucite. H. Rosenbusch, 1905. Mikroskopische Physiographie d. Mineralien, 4th edit., vol. i, part 2, p. 33 (Paläoleucit). The original mineral of pseudoleucite. *See* Soda-leucite.

Palmerite. E. Casoria, 1904. Atti R. Accad. Georgofili, Firenze, ser. 5, vol. i, p. 293; Ann. R. Scuola Sup. Agric. Portici, 1904, vol. vi. Hydrated aluminium potassium phosphate, $HK_2Al_2(PO_4)_3 . 7H_2O$, occurring as a white powder under bat-guano in a cave on Monte Alburno, Salerno, Italy. Named after Paride Palmeri, professor of chemistry in the Royal School of Agriculture at Portici, near Naples.

Palmierite. A. Lacroix, 1907. Compt. Rend. Acad. Sci. Paris, vol. cxliv, p. 1400 (palmiérite). Minute hexagonal scales which are optically uniaxial with strong negative birefringence; found enclosed in aphthitalite amongst the products of the Vesuvian eruption of April, 1906. Anhydrous sulphate of lead, potassium, and sodium, $PbSO_4 . (K,Na)_2SO_4$. Named after Luigi Palmieri (1807–96).

Paracelsian. E. Tacconi, 1905. Rend. R. Istit. Lombardo, ser. 2, vol. xxxviii, p. 642 (Paracelsiana). A mineral with the composition $Ba_3Al_8Si_8O_{31}$, occurring as pale yellow granules in veins in crystalline schists at Candoglia, Piedmont. It is near to celsian ($BaAl_2Si_2O_8$) in composition and optical characters, but it seems to differ from this in possessing only poor cleavage.

Paratacamite. G. F. H. Smith, 1905. Nature, vol. lxxi, p. 574; Min. Mag., 1906, vol. xiv, p. 170; Zeits. Kryst. Min., 1907, vol. xliii, p. 28. Hydrated oxychloride of copper, $Cu_2Cl(OH)_3$, dimorphous with atacamite. The bright green crystals are rhombohedral but with optical anomalies. From Chili.

Paravivianite. S. P. Popoff, 1906. Centralblatt Min., 1906, p. 112. A variety of vivianite with part of the iron replaced by small amounts of manganese and magnesium, $(Fe,Mn,Mg)_3P_2O_8 . 8H_2O$. Occurs as blue, acicular crystals in limonitic iron-ore in South Russia.

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Patronite. F. Hewett. Engineering and Mining Journ. New York, 1906, vol. lxxxii, p. 385. C. Matignon, Revue Scientifique, Paris, 1906, ser. 5, vol. vi, p. 597. A dark green mineral containing much vanadium, perhaps vanadium sulphide, but not yet completely determined. It occurs with vanadiferous asphaltum near Cerro de Pasco in Peru. Named after Antenor Rizo Patrón, of the Huaraucaca smelting works near Cerro de Pasco, who detected the vanadium.

Pearcit. P. Groth, Tabell. Uebersicht d. Mineralien, 4th edit., 1898, p. 88. Error for pearceite: named after Dr. Richard Pearce.

Pholidite. C. Hintze, 1892. Handbuch d. Mineralogie, vol. ii, p. 885 footnote (Pholidit). The more correct derivation of pholerite, from φολίς, φολίδος, a scale; a scaly variety of kaolinite.

Phosphorus. Evidence of the existence of native phosphorus in a meteoric stone is adduced by O. C. Farrington, Amer. Journ. Sci., 1903, ser. 4, vol. xv, p. 71; Chem. News, 1903, vol. lxxxvii, p. 66.

Picrocrichtonite. (Collection de Minéralogie du Muséum d'Histoire Naturelle, Paris, Guide du Visiteur, 2nd edit., 1900, p. 24.) A. Lacroix, Minéralogie de la France, 1901, vol. iii, p. 284. Synonym of picroilmenite $(Fe,Mg)TiO_3$ (compare Min. Mag., vol. xiv, p. 165). Lacroix distinguishes between crichtonite ($FeTiO_3$) and ilmenite ($FeTiO_3 . xFe_2O_3$); hence the above name for the magnesian variety.

Podolite. W. Tschirwinsky, 1907. Centralblatt Min., 1907, p. 279 (Podolit). A mineral closely related to apatite and staffelite, but with the composition $3Ca_3(PO_4)_2 . CaCO_3$, occurring as minute hexagonal crystals in phosphorite nodules in govt. Podolia, South Russia. It had earlier been called carbapatite (q. v.).

Prasiolite. C. Hintze, Handbuch d. Mineralogie, 1892, vol. ii, p. 940 (Prasiolith). Variant of praseolite (Praseolit, A. Erdmann, 1842). Hintze gives as derivation πράσιος, leek-green, and λίθος, stone; whilst Erdmann gives πράσον, leek, and λίθος.

Priorite. W. C. Brögger, 1906. Videnskabs-Selsk. Skrifter, Kristiania, 1906, no. 6, p. 110 (Priorit). A titano-niobate of yttrium, cerium-earths, &c., found as indistinct orthorhombic crystals in the tin-gravels of Swaziland, South Africa. Named after Dr. George Thurland Prior, of the British Museum, who analysed it (Min. Mag., 1899, vol. xii, p. 96). It is isomorphous with blomstrandine (q.v.) and dimorphous with euxenite, the four minerals euxenite-polycrase and priorite-blomstrandine forming an isodimorphous group.

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Pseudo-jade. A name which may be applied to any mineral resembling jade in appearance; for example, bowenite (C. A. McMahon, Min. Mag., 1890, vol. ix, p. 187).

Pseudomeionite. H. Rosenbusch, 1902. Mitt. Grossherz. Badisch. geol. Landesanst., vol. iv, p. 391 (Pseudomejonit). A name provisionally given to a felspathoid mineral occurring with bytownite in a para-amphibole-gneiss from the Black Forest; it has the microscopical characters of meionite, except in possessing a good basal cleavage.

Pseudowollastonite. E. T. Allen and W. P. White, 1906. Amer. Journ. Sci., ser. 4, vol. xxi, p. 89 (Pseudo-Wollastonite). An artificial product usually known as hexagonal calcium metasilicate: the crystals are, however, pseudo-hexagonal and probably monoclinic. Wollastonite when heated to 1180° C. becomes changed, without melting, into this dimorphous modification.

Purpurite. L. C. Graton and W. T. Schaller, 1905. Amer. Journ. Sci., ser. 4, vol. xx, p. 146; Zeits. Kryst. Min., 1906, vol. xli, p. 433. A hydrous manganic ferric phosphate, $2(Mn,Fe)PO_4 . H_2O$, with a purple or dark reddish colour; hence the name, from the Latin, purpura, purple. It is probably orthorhombic, and occurs in small irregular masses as an alteration product of lithiophilite and triphylite in the lithium-bearing pegmatite-veins of North Carolina and of San Diego Co., California.

Radiobaryt. J. Knett, 1904. Sitzungsber. Akad. Wiss. Wien, vol. cxiii, Abt. IIa, p. 761. Crystals of barytes from the hot springs of Carlsbad, Bohemia, but not crystals from other localities, were found to be radio-active (as demonstrated by their action on a photographic plate).

Radiotine. R. Brauns, 1904. Neues Jahrb. Min., Beil.-Bd. xviii, p. 314 (Radiotin). Small spheres with radially fibrous structure occurring in a serpentine which has resulted from the alteration of picrite near Dillenburg, Nassau. It has the same composition as serpentine ($H_4Mg_3Si_2O_9$), but differs from this in not being attacked by hydrochloric acid and in its higher specific gravity of 2·70. So named because of its radial structure and its relation to serpentine.

Rancieite. (Collection de Minéralogie du Muséum d'Histoire Naturelle, Paris, Guide du Visiteur, 2nd edit., 1900, p. 29 (Ranciéite).) The correct spelling of rancierite (A. Leymerie, 1857), a variety of wad (hydrated manganese oxide) from the iron-mines of Rancié, Ariège, France.

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Reyerite. F. Cornu, 1906. Min. Petr. Mitt. (Tschermak), 1906–7, vol. xxv, pp. 211, 519 (Reyerit). A 'micaceous zeolite' indistinguishable in appearance from gyrolite and zeophyllite. The thin plates with perfect cleavage and pearly lustre are rhombohedral and form radial aggregates. Sp. gr. 2·499—2·578; refractive index (ω) 1·564. Hydrous silicate of calcium with a little aluminium. The specimens examined were collected in Greenland by C. L. Giesecke in 1807–13, and the mineral is probably identical with his 'Glimmerzeolith' (see Min. Mag., vol. xiv, p. 95). Named after Professor Eduard Reyer, of Vienna.

Romanechite. (Collection de Minéralogie du Muséum d'Histoire Naturelle, Paris, Guide du Visiteur, 2nd edit., 1900, p. 29 (Romanéchite).) Psilomelane from Romanèche, France, with the composition $(Ba,Mn)O.3MnO_2.H_2O$; analysed by A. Gorgeu (1890).

Rosolite. (Trans. Amer. Inst. Mining Engin., 1902, vol. xxxii, pp. 55, 57.) A rose-pink garnet from Mexico. *See* Landerite.

Rutherfordine. W. Marckwald, 1906. Centralblatt Min., 1906, p. 763 (Rutherfordin). A yellow uranyl carbonate, $UO_2.CO_3$, resembling uranochre in appearance and resulting by the alteration of uraninite; from German East Africa. It is strongly radio-active, and is named after a prominent worker in radio-activity, Professor Ernest Rutherford, of Manchester, formerly of the McGill University, Montreal. Not to be confused with rutherfordite (C. U. Shepard, 1851) from Rutherford Co., North Carolina.

Schertelite. Zeits. Kryst. Min., 1906, vol. xlii, p. 386 (Schertelit). The correct spelling of schertalite (R. W. E. MacIvor, 1902; third list, Min. Mag., vol. xiii, p. 376). Named after Arnulf Schertel (1841–1902), formerly professor in the Bergakademie of Freiberg, Saxony.

Schuppenglanz. *See* Lepidolamprite.

Silicomagnesiofluorite. P. A. Zemlatčenskij, 1906. Zeits. Kryst. Min., vol. xlii, p. 209 (Silicomagnesiofluorit). Ash-grey, greenish, or bluish, radially-fibrous aggregates associated with quartz and serpentine, in a boulder at Luppiko, Finland. The fibres are optically positive and give straight extinction. Formula, $H_2Ca_4Mg_3Si_2O_7F_{10}$. So named on account of its composition.

Smithite. R. H. Solly, 1905. Min. Mag., vol. xiv, p. 74. (A preliminary description of the unnamed mineral appeared in Nature, 1903, vol. lxix, p. 142.) G. F. H. Smith and G. T. Prior, Min. Mag., 1907, vol. xiv, p. 293. Minute, red, monoclinic crystals found in the white,

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crystalline dolomite of the Binnenthal, Switzerland. Sulpharsenite of silver, $AgAsS_2$. Named after Dr. George Frederick Herbert Smith, of the British Museum.

Soda-leucite. An analysis of pseudoleucite, consisting of a mixture of orthoclase, nephelite, scapolite, &c., showed the presence of 7·08 per cent. Na_2O with 8·49 per cent. K_2O; this suggests that the original mineral was a soda-leucite (C. W. Knight, Amer. Journ. Sci., 1906. ser. 4, vol. xxi, p. 292). A soda-leucite (Natronleucit) was prepared artificially by J. Lemberg in 1876. *See* Palaeoleucite.

Sommairite. (British Museum (Natural History), Students' Index to the Collection of Minerals, 1897. Collection de Minéralogie du Muséum d'Histoire Naturelle, Paris, Guide du Visiteur, 2nd edit., 1900, p. 32.) Zinciferous melanterite from Laurion, Greece; analysed, but not named sommairite, by L. Michel (Bull. Soc. franç. Min., 1893, vol. xvi, p. 204).

Soretite. L. Duparc and F. Pearce, 1903. Arch. Sci. Phys. Nat. Genève, ser. 4, vol. xvi, p. 599 (Soretite); Bull. Soc. franç. Min., vol. xxvi, p. 126 (sorétite). A variety of common aluminous hornblende, defined by its optical characters, which vary, however, in different specimens. It occurs in anorthite-diorite at Koswinsky Kamen, northern Urals. Named after the late Professor Charles Soret (1854–1904), of Geneva.

Souesite. G. C. Hoffmann, 1905. Amer. Journ. Sci., ser. 4, vol. xix, p. 319. A native nickel-iron alloy occurring as small, rounded grains in the auriferous gravels of the Fraser River, British Columbia. Named after F. Soues, who sent the material for identification.

G. S. Jamieson (Amer. Journ. Sci., 1905, ser. 4, vol. xix, p. 413; Zeits. Kryst. Min., 1905, vol. xli, p. 157) points out that awaruite, josephinite, souesite, and other terrestrial nickel-iron alloys have no definite composition, though they all lie between $FeNi_3$ and $FeNi_2$; and he proposes that they should all be referred to the earliest name awaruite (W. Skey, 1885).

Spandite. L. L. Fermor, 1907. Records Geol. Survey India, vol. xxxv, p. 22. The term spessart-andradite, contracted to spandite, is applied to garnets intermediate in chemical composition between spessartite and andradite.

Stilpnochlorane. F. Kretschmer. 1905. Centralblatt Min., 1905, p. 203; 1907, p. 292 (Stilpnochloran). A chloritic mineral occurring

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as shining, yellow scales in the iron-mines at Gobitschau, Moravia. It is an alteration product of thuringite, and has the composition $H_{24}(Al,Fe)_{10}(Ca,Mg)Si_9O_{46}$. Named from στιλπνός, glistening, and χλωρός, pale-green, yellow.

Strüverite. F. Zambonini, 1907. Rend. Accad. Sci. Napoli, ser. 3, vol. xiii, p. 35. A black, tetragonal mineral, with angles near those of rutile and tapiolite, found in pegmatite at Craveggia, Piedmont. In chemical composition it is near to ilmenorutile. Named after Professor Giovanni Strüver, of Rome. Not the strüverite of A. Brezina, 1876.

Synkysit. O. B. Boeggild, Mineralogia Groenlandica, Copenhagen, 1905, p. 167. Variant of synchysite (G. Flink, 1901).

Tarbuttite. L. J. Spencer, 1907. Nature, vol. lxxvi, p. 215. Hydrous phosphate of zinc occurring as colourless or faintly coloured, anorthic crystals with descloizite at the Rhodesia Broken Hill mines, North Western Rhodesia. The crystals have a perfect cleavage in one direction, through which emerges obliquely the acute, negative bisectrix of the optic axes. Named after Mr. Percy Coventry Tarbutt, a director of the mining company, who furnished the material for determination.

Teallite. G. T. Prior, 1904. Min. Mag., vol. xiv, p. 21. Sulphostannite of lead, $PbSnS_2$, occurring as black, metallic, soft, and flexible folia resembling graphite, which are orthorhombic with a perfect basal cleavage. Named after Dr. J. J. Harris Teall, Director of the Geological Survey of Great Britain. From Bolivia; R. Koechlin (Min. Petr. Mitt. (Tschermak), 1905, vol. xxiv, p. 114) gives a more definite locality.

Thorianite. W. R. Dunstan, 1904. Nature, vol. lxix, p. 510; Bull. Imp. Inst. London, 1904, vol. ii, p. 13; 1905, vol. iii, p. 155. W. R. Dunstan and G. S. Blake, Proc. Roy. Soc. London, 1905, ser. A, vol. lxxvi, p. 253. W. R. Dunstan and B. M. Jones, Proc. Roy. Soc. London, 1906, ser. A, vol. lxxvii, p. 546. A heavy, black mineral found as water-worn, cubic crystals in the gem-bearing gravels of Ceylon. It was first described as uraninite (A. K. Coomaraswamy, Spolia Zeylanica, 1904, vol. i, p. 112; Administration Reports, Ceylon, for 1903, 1904, part iv, p. L 11), but it differs from this in that the uranium oxide (UO_2) is largely replaced isomorphously by thoria (58·8—78·8 per cent. ThO_2). So named because of the large amount of thorium which it contains.

Titanaugite. A. Knop, 1892. Der Kaiserstuhl im Breisgau. Leipzig, p. 72 (Titan-Augit). Titaniferous augite.

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Titaneisenglimmer. H. Rosenbusch, 1885. Mikroskopische Physiographie d. Mineralien, 2nd edit., vol. i, p. 331. Ilmenite as thin, transparent scales of a clove-brown colour by transmitted light; described by K. Hofmann (1879) in basaltic rocks from Hungary. *See* Ilmenitglimmer.

Titanmelanite. A. Knop, 1892. Der Kaiserstuhl im Breisgau. Leipzig, p. 145 (Titanmelanit). Titaniferous melanite approaching schorlomite in composition.

Trechmannite. R. H. Solly, 1904. Min. Mag., 1905, vol. xiv, pp. 75, 189. (A preliminary description of the unnamed mineral appeared in Nature, 1903, vol. lxix, p. 142, and the name (Trechmannit) was first printed in Min. Petr. Mitt. (Tschermak), 1904, vol. xxiii, p. 552.) G. F. H. Smith and G. T. Prior, Min. Mag., 1907, vol. xiv, p. 300. Minute, red crystals associated with tennantite, &c., in the white, crystalline dolomite of the Binnenthal, Switzerland. The crystals are rhombohedral with parallel-faced hemihedrism, and were found to contain silver and arsenic: probably a sulpharsenite of silver. Named after Dr. Charles O. Trechmann, of Castle Eden, Co. Durham.

Tschernichewite. L. Duparc and F. Pearce, 1907. Compt. Rend. Acad. Sci. Paris, vol. cxliv, p. 763 (tschernichéwite). A variety of amphibole occurring with magnetite in a quartzite in the northern Urals. It is defined by its optical characters: the plane of the optic axes is perpendicular to the plane of symmetry and the axial angle is near 90°; $\gamma : c = 4°$; the pleochroism is very strong. These characters point to a soda-iron-amphibole near riebeckite or arfvedsonite; compare osannite. Named after Theodosij Nikolajevič Černyšev (Tschernyschew), Director of the Geological Survey of Russia.

Tychite. S. L. Penfield and G. S. Jamieson, 1905. Amer. Journ. Sci., ser. 4, vol. xx, p. 217; Zeits. Kryst. Min., vol. xli, p. 285. Octahedral crystals indistinguishable in appearance from northupite, and differing from this in containing sodium sulphate in place of sodium chloride, the formula being $2MgCO_3 . 2Na_2CO_3 . Na_2SO_4$. Amongst several thousand crystals of northupite from Borax Lake, San Bernardino Co., California, only four crystals of tychite were found, and the first one only by the merest chance, hence the name, from τύχη, luck. The formula was determined by the analysis of artificially prepared crystals. Mixed crystals containing the northupite and tychite molecules in varying proportions have been prepared by A. de Schulten (Compt. Rend. Acad. Sci. Paris, 1906, vol. cxliii, p. 403).

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Weinbergerite. F. Berwerth, 1906. Min. Petr. Mitt. (Tschermak), vol. xxv, p. 181 (Weinbergerit). Radially-fibrous aggregates occurring with diopside and bronzite in the meteoric iron of Kodaikanal, India. The optical characters agree with orthorhombic symmetry. $(Na,K)_2O.6(Fe,Ca,Mg)O.Al_2O_3.8SiO_2$ or $R'AlSiO_4 + 3R''SiO_3$. Named after J. Weinberger, of Vienna.

Winchite. L. L. Fermor, 1906. Trans. Mining and Geol. Inst. India, vol. i, p. 79. A blue amphibole closely allied to tremolite in chemical composition, but containing also iron, sodium, potassium, and manganese. Found by Howard J. Winch with manganese-ores in Central India. A preliminary description of the mineral was given by L. L. Fermor in 1904 (Records Geol. Survey India, vol. xxxi, p. 235).

Xalostocite. (Collection de Minéralogie du Muséum d'Histoire Naturelle, Paris, Guide du Visiteur, 2nd edit., 1900, p. 49.) The pink grossularite occurring in white marble at Xalostoc, Morelos, Mexico. See Landerite.

Yttrocalcite. E. S. Fedorov, 1905. Gornyi Zhurnal, St. Petersburg, year lxxxi, vol. iii, p. 264 (иттрокальцитъ). Described as a fluoride of calcium, yttrium, and cerium, but found on further examination to be identical with fluor-apatite (Ann. Rep. Progr. Chem. Soc. London, 1907, for 1906, vol. iii, p. 311).

Yttrocrasite. W. E. Hidden and C. H. Warren, 1906. Amer. Journ. Sci., ser. 4, vol. xxii, p. 515; Zeits. Kryst. Min., 1907, vol. xliii, p. 18. Hydrous titanate of yttrium-earths, thorium, uranium, &c., found in Burnet Co., Texas, as black, orthorhombic crystals with a pitchy lustre and uneven fracture. Apparently so named because of its resemblance in appearance to polycrase (from κρᾶσις, a mixing), though it contains no more yttrium than does polycrase.

Zeiringit. *See* Zeyringite.

Zeolite mimetica. G. D'Achiardi, 1906. Atti Soc. Toscana Sci. Nat., Mem., vol. xxii, p. 160. A zeolitic mineral from Elba was determined to have the form of octagonal prisms built up of sectors with different optical orientation, and to have the composition $(Ca,K_2,Na_2)_3Al_4(Si_2O_5)_9.14H_2O$. Had the author been in no doubt as to this being really a new mineral he would not have hesitated to call it 'dachiardite' (p. 164) in memory of his father, Antonio D'Achiardi (1839–1902); for the present, however, he prefers to call it 'zeolite mimetica'.

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Zeyringite. — Pantz, 1811. Taschenb. Min. (Leonhard), vol. v, p. 373 (Zeyringit). A finely fibrous, greenish-white or sky-blue calcareous sinter containing nickel, from Zeyring, Styria. It is placed under aragonite by V. von Zepharovich (Min. Lexicon Österreich, 1859, vol. i, p. 28) and E. Hatle (Die Minerale des Herzogthums Steiermark, 1885, p. 68); the latter spells Zeiringit.

SYSTEMATIC CLASSIFICATION OF NEW MINERALS[1].

Element.

Phosphorus.

Silicide.

Moissanite, CSi.

Sulphide.

Patronite, (vanadium sulphide ?).

Sulpharsenites, &c.

Teallite, $PbSnS_2$.
Smithite, $AgAsS_2$.
Hutchinsonite, $(Tl,Cu,Ag)_2PbAs_4S_8$.
Trechmannite. (Contains Ag,As.)
Lengenbachite, $Pb_6(Ag,Cu)_2As_4S_{13}$.
Marrite.

Haloids.

Cryolithionite, $Li_3Na_3Al_2F_{12}$.
Kleinite, $Hg_4Cl_2O_3$.
Paratacamite, $Cu_3Cl(OH)_3$.
Chlormanganokalite, $MnCl_2 . 4KCl$.

Oxides.

Thorianite, $(Th,U)O_2$.
Coronadite, $(Pb,Mn)O . 3MnO_2$.
Hollandite,
$m(Ba,Mn)_2MnO_5 + nFe_4(MnO_5)_3$.
Ebelmenite, var. of psilomelane.
Romanechite, „ „

Carbonates.

Kutnohorite, $(Ca,Mn,Fe,Mg)CO_3$.
Rutherfordine, $UO_2 . CO_3$.
Tychite,
$2MgCO_3 . 2Na_2CO_3 . Na_2SO_4$.
Otavite, basic Cd carbonate.
Giorgiosite,
$4MgCO_3 . Mg(OH)_2 . 4H_2O$.

Sulphates.

Metanhydrite, $CaSO_4$.
Palmierite, $PbSO_4 . (K,Na)_2SO_4$.
Sommairite, $(Fe,Zn)SO_4 . 7H_2O$.
Doughtyite,
$Al_2(SO_4)_3 . 5Al_2(OH)_6 . 21H_2O$.

Phosphates.

Podolite, $3Ca_3(PO_4)_2 . CaCO_3$.
Purpurite, $2(Mn,Fe)PO_4 . H_2O$.
Gorceixite,
$BaO . 2Al_2O_3 . P_2O_5 . 5H_2O$.
Harttite,
$SrO . 2Al_2O_3 . P_2O_5 . SO_3 . 5H_2O$.
Palmerite, $HK_2Al_2(PO_4)_3 . 7H_2O$.
Kertschenite,
$(Fe,Mn,Mg)O . Fe_2O_3 . P_2O_5 . 7H_2O$.
Paravivianite,
$(Fe,Mn,Mg)_3(PO_4)_2 . 8H_2O$.
Tarbuttite, Hyd. phosp. Zn.

[1] Only the more important of the names given in the above alphabetical list are here included.

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Borate.

'Octahedral borax,' $Na_2B_4O_7 . 5H_2O$.

Tantalates, Titanates, &c.

Marignacite.
Blomstrandine.
Priorite.
Yttrocrasite.
Strüverite.

Silicates.

Isorthose, var. of orthoclase.
Baryta-orthoclase.
Paracelsian, $Ba_2Al_2Si_3O_{21}$.
Tschernichewite, var. of amphibole.
Soretite, ,, ,,
Osannite, ,, ,,
Winchite, ,, ,,
Magnesium-diopside.
Blanfordite, var. of pyroxene.
Soda-leucite.
Landerite, var. of grossularite.
Naegite [= zircon ?].
Californite, var. of idocrase.
Beckelite, $Ca_3Ce_4(Si,Zr)_3O_{15}$.
Weinbergerite, $(Na,K)_2(Fe,Ca,Mg)_6Al_2Si_8O_{26}$.
Beryllium-humite, $(Mg,Be)_5(MgOH)_2(SiO_4)_3$.
Oehrnite, $6(Mg,Fe,Ca)SiO_3 . H_2O$.
Hibschite, $H_4CaAl_2Si_2O_{10}$.
Astrolite, $(Al,Fe)_2Fe''(Na,K)_2(SiO_3)_5 . H_2O$.
Silicomagnesiofluorite, $H_2Ca_4Mg_3Si_2O_7F_{10}$.
Erikite, hyd. sil. and phosphate, Ce,Al,Ca,Na.
Morencite, $H_{22}(Mg,Ca)_2Fe_6'''(SiO_4)_{11}$.
Radiotine, $H_4Mg_3Si_2O_9$.
Nemaphyllite, $H_4Mg_2Si_2O_9$.
Nepouite, $(Ni,Mg)_3Si_2O_7 . 2H_2O$.
Chocolite, hyd. sil. Fe,Ni,Mg.
Greenalite, $Fe'''_2(Fe,Mg)_3(SiO_4)_3 . 3H_2O$.
Irvingite, var. of lithia-mica.
Moravite, $H_4(Al,Fe)_4(Fe,Mg)_2Si_7O_{24}$.
Stilpnochlorane, $H_{24}(Al,Fe)_{10}(Ca,Mg)Si_9O_{46}$.
Zeolite mimetica, $(Ca,K_2,Na_2)_2Al_4(Si_2O_5)_9 . 14H_2O$.
Reyerite, hyd. sil. Ca,Al.

Hydrocarbons.

Denhardtite.
N'hangellite.

July, 1907.

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REVIEWS.

Rock Minerals: their Chemical and Physical Characters and their Determination in thin Sections. By JOSEPH P. IDDINGS. Pp. xii + 548, with 438 text-figures and one coloured plate. (New York: John Wiley & Sons; London: Chapman & Hall, 1906. Price 21*s.* net.)

THIS extremely valuable treatise on rock-forming minerals covers practically the same ground as the same author's translation and abridgement of Rosenbusch's 'Microscopical Physiography of Rock-making Minerals', which between 1888 and 1898 passed through four English editions; it is evidently intended to take the place of a translation and abridgement of the still more extensive fourth edition of the German work prepared by Rosenbusch and Wülfing. In many respects the present volume is a distinct improvement on the translated work. The arrangement of the subject-matter under prominent headings makes the volume much more useful for purposes of reference.

The first part, dealing with general principles and methods of research, extends to 200 pages, half of which is devoted to optical properties. In the second, and larger, part is given a detailed description of the various rock-forming minerals. Information respecting each mineral is clearly put forth under the following headings:—chemical composition; alteration; crystallographic characters (including twinning and cleavage); optical properties (and colour); inclusions; modes of occurrence; resemblances to, and differences from, other minerals; laboratory production. Some of the longer descriptions are preceded by a summary of the characters of the mineral, or, in the case of groups of minerals, by a general account of the group. The minerals are classified on a chemical basis, and this seems more rational than the classification according to systems of crystallization as adopted by Rosenbusch.

At the end of the volume are given useful tables of optical constants, which have the advantage of being printed on the pages rather than on inconvenient folding sheets. The coloured plate exhibiting the birefringence of minerals is borrowed from Lévy and Lacroix.

The book is one to be recommended to all students of petrology, but it would perhaps have been more generally useful if references to the literature had been quoted under each mineral. A few misprints have been noticed, especially in the spelling of the names of minerals.

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Physikalische Kristallographie vom Standpunkt der Strukturtheorie. By ERNST SOMMERFELDT. Pp. vi + 132, with 122 illustrations. (Leipzig: C. H. Tauchnitz, 1907. Price 6 marks.)

EVEN with the addition of the last four words, which on the title-page are appended in smaller type and on the cover do not appear at all, the scope of the book can scarcely be said to be defined with much precision by its title. Far from dealing with the general characters of crystals and the methods and apparatus in use for their determination, Dr. Sommerfeldt confines himself, except in the last chapter, to a discussion of the various types of crystal-structure, the point-systems of Sohncke being treated in far greater detail. The proper comprehension of the symmetry appertaining to the several systems is considerably facilitated by the series of photographic reproductions of the actual models, which were constructed under the direction of Sohncke, and are preserved at Munich. The absence of relief unavoidable in such illustrations, unless presented in pairs for observation with a stereoscope, is to some extent compensated by a plan placed beside each illustration; unfortunately many of the latter diagrams are far from distinct. After defining in this way the 65 point-systems, the author determines, somewhat too cursorily, the remaining 165 systems possible in crystals by means of the method due to Barlow. This procedure is more easily understood by most crystallographers than the mathematical method of Schönflies, and it has the advantage of distinguishing clearly the enantiomorphous systems from those possessing mirror-image symmetry.

In the concluding chapter, Dr. Sommerfeldt treats briefly of many interesting physical questions closely connected with the discussion of crystal-structure; such as the etching-figures, which have thrown so much light on the internal symmetry of certain substances; the rotation of the plane of polarization, a phenomenon which can only be satisfactorily explained by the existence of some helical arrangement in the structure; cleavage, which suggested to Haüy the idea of a primitive form; isomorphism, morphotropy, and polymorphism; twinning; and the cause of the habit of crystals. The chapter ends with a discussion of the well-known case of pseudo-trigonal symmetry, which can be obviated only by admitting the idea of a grained structure.

Despite a want of balance in the discussion and some inexactitude in the reasoning, the book is one which may be commended to the reader who desires a comparatively simple exposition of the difficult and important subject of crystal-structure.

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NOTES.

THE following deaths have to be recorded:—

LUDWIG BRACKEBUSCH died at Hanover on June 2, 1906, at the age of fifty-seven. For many years he was Professor of Mineralogy and Geology in the University of Córdoba, Argentina, and he was the author of several papers on Argentine minerals. The mineral brackebuschite was named after him.

WILLIAM PAGET JERVIS (1831–1906) was born in India, where his father, Colonel T. B. Jervis, was engaged on the Topographical Survey, and after an English education and some practical experience in Cornish mining, he was appointed Conservator of the Royal Italian Industrial Museum at Turin. He published several papers on the mineral resources of Italy, and his 'I tesori sotterranei dell' Italia' (4 vols., 1873–89) is a monument of patient and painstaking industry. He was created a Cavaliere by the King of Italy.

HENRI MOISSAN (1852–1907), the celebrated French chemist, died on February 20, 1907, following an operation for appendicitis. Since 1900 he had been Professor of Inorganic Chemistry at the Sorbonne. On January 10 of this year he was elected President of the French Mineralogical Society. His researches on meteoric irons and on the artificial production of diamond are well known. A meteoric mineral recently isolated by him has been named moissanite.

VIKTOR IVANOVIČ VOROBJEV (V. von Worobieff), Conservator of the collection of minerals in the Geological Museum of the Academy of Sciences at St. Petersburg, was killed on a glacier in the Caucasus, in August, 1906, at the early age of thirty-one. His elaborate paper on the crystalline form and pyroelectric properties of tourmaline gave promise of further useful work.

JOHN FRANCIS WALKER (1839-1907), an original member of this Society, died at York, his native city, on May 23, 1907. He made geology, and more particularly British fossil brachiopods, his special study, though at one time he was a University teacher in chemistry at Cambridge

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The Chair of Mineralogy at the University of Bonn, rendered vacant by the resignation of Professor H. Laspeyres, has been filled by Professor R. Brauns, whose place at Kiel has been taken by Professor E. A. Wülfing, of the Technical High School of Danzig; the last-named place being

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now filled by Dr. F. von Wolff. Professor L. Milch, of Breslau, goes to Greifswald as successor to the late E. Cohen, and Dr. C. M. Viola becomes Professor of Mineralogy at Parma.

The seventieth birthdays of Professors H. Rosenbusch and G. Tschermak, celebrated last year (1906), were marked by the publication of a 'Harry Rosenbusch Festschrift' and of a special number of 'Tschermak's Mineralogische und Petrographische Mitteilungen', in which are given excellent portraits of these well-known workers in petrology and mineralogy respectively.

The extensive private collection of minerals and fossils formed during the course of many years by the late Miss Caroline Birley (1851–1907) has been bequeathed by her to the Trustees of the British Museum and to the Manchester Museum in the University of Manchester. The collection is particularly rich in zeolites, and more especially in zeolites from the Faroe Islands. Shortly before Miss Birley's visits to this locality in 1889 and 1890, there had been an extensive fall of rock, and she was thus fortunately able to collect many fine specimens. The description of 'sphaerostilbite', published in this magazine (1898, vol. xii, pp. 26–9), was based on material in Miss Birley's collection.

The unique collection of jade presented by Mr. Heber R. Bishop to the Metropolitan Museum of Art in New York is described in two huge volumes entitled 'Investigations and Studies in Jade' (New York, 1906) The volumes measure 19 × 26 inches, and weigh respectively 70 and 55 pounds. The paper, printing, and binding are of the best obtainable, whilst the plates are veritable works of art, reproducing the translucency and colour of the mineral with extraordinary faithfulness. In addition to the catalogue of the collection, there are several articles, contributed by well-known experts, dealing with jade (nephrite and jadeite) from every possible point of view. The mineralogical portion, of which Dr. G. F. Kunz had charge, contains articles by Max Bauer, F. Berwerth, F. W. Clarke, A. A. Damour, J. P. Iddings, L. A. Jaczewski, G. F. Kunz, A. B. Meyer, C. Palache, S. L. Penfield, L. V. Pirsson, S. H. Washington, and E. Weinschenk, besides fifty-eight new analyses by P. T. Walden and H. W. Foote. The work was privately printed and the edition limited to 100 copies, which have been distributed amongst the important libraries of the world, a dozen copies coming to the United Kingdom. Unfortunately Mr. Bishop did not live to see the completion of this truly remarkable work.

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INDEX TO VOL. XIV.

(See also 'List of New Mineral Names,' p. 394.

Aegirite-riebeckite-gneiss from Ross-shire, 119.
Albite from Binnenthal, 16.
— German East Africa, 178.
Allen (E. T.), synthesis of minerals, 281.
Allophane from Wales, 168.
Alum, crystallization of, 184.
Amethyst from German East Africa, 178.
Amiantos of ancients = chrysotile, 148.
Ammonium haloids, 235.
Amphibole in serpentine-rock, 366.
Anatase in Cleveland ironstone, 96, 98.
— from Binnenthal, 16.
Andorite from Bolivia, 316.
— systematic position of, 319.
Antigorite in serpentine-rock, 368.
Antimonite, optical characters, 199.
Apatite from Bolivia, 338.
Appointments to chairs of mineralogy, 418.
Arsenopyrite, *see* Mispickel.
Augelite from Bolivia, 323.
Aurichalcite from Cornwall, xxviii.
— Co. Wicklow, 349.

Babel-quartz from Cornwall, xxvii.
Baddeleyite from Ceylon, 378.
Balance-sheet, xxiv, xxx, xl, xliv.
Barker (T. V.), regular growth of soluble salts on each other, 235.
— elected member, xxv.
Barlow (W.), atom-arrangements of crystals in carbon compounds, xxii.
Barrow (G.), axinite from Bodmin district, xxxvi.
Barytes from Binnenthal, 190.
— Co. Tipperary, 352.
Bastite in serpentine-rock, 370.
Baumhauer (H.), elected hon. member, xxxi.
Becke (F.), skiodroms, 276.
— measurement of optic axial angle from isogyres, 280.
Becker (G. F.) and Day (A. L.), linear force exerted by growing crystal, 107.
Behrens (T. H.), obituary, 118.
Bertrandite from Cornwall, xxvii.
Bethany meteorite, 35.
Binnenthal (Switzerland) minerals, xxxiv, xliii, 16, 72, 184, 204, 212, 288, 389.
Birley (Miss C.), collection, 419.
Bishop (H. R.), collection of jade, 419.
Blake (G. S.), elected member, xxxvi.
— and Smith (G. F. H.), baddeleyite from Ceylon, 378.
Blende with metallic lustre, from the Binnenthal, 81.
Boeggild (O. B.), 'Mineralogia Groenlandica,' 195.
Bolivian minerals, 21, 208, 308, 345.
— rocks, 335.
Bonney (T. G.), obituary of C. A. McMahon, 56.
Bornite, formula of, 120.
Bowman (H. L.), hamlinite from Binn, 389.
— bertrandite from Cornwall, xxvii.
Bowmanite, 80, 389, 396.
Brackebusch (L.), obituary, 418.
British minerals, xxvii, xxviii, xxxvi, xxxix, 93, 96, 98, 109, 116, 118, 167, 207, 311, 348, 350, 385.
Brookite in Cleveland ironstone, 96.
Butler (F. H.), silver-ore in Perran mine, Cornwall, 385.
Bye-laws, vii.

Caesium haloids, 235.
Calamine-ore from Co. Tipperary, 351.
Caledonite from Co. Wicklow, 348.
Campbell (D. F.), elected member, xix.
Canadian economic minerals, 196.
Cape of Good Hope meteorite, 37.
Caperr meteorite, 41.
Carborundum, 121, 396.
Cassiterite from Bolivia, 332.
— Ross-shire, 118.
— pseudomorphs from Bolivia, 345.
Cerargyrite from Cornwall, 385.
Cerussite, angles, 51.
Ceylon, minerals from, 43, 160, 194, 378.

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Chalcostibite from Bolivia, 322.
Chalybite from Bolivia, 342.
— Cornwall, 385.
Chapman (E. J.), obituary, 65.
Chemical analysis of rocks, 115.
Chevalier (J.), crystallization of potash-alum, 134.
— and Miers (H. A.), crystallization of sodium nitrate, 123.
Chlormanganokalite, 397.
Chlornatrokalite, 397.
Chrysotile from Canada, 196.
— Cyprus, 143.
— in ancient writings, 143.
Church (A. H.), handbook of precious stones, 194.
Claremont (L.), the gem-cutter's craft, 275.
Cleve (P. T.), obituary, 194.
Cleveland ironstone, brookite, &c. in, 96.
Clinochlore in serpentine-rock, 367.
Cohen (E. W.), obituary, 194.
Colombia (S. America), minerals, 196.
Copper from Bolivia, 309.
Cornish minerals, xxvii, xxviii, xxxvi, 311, 385.
Corundum from German East Africa, 178.
Crook (T.), elected member, xli.
— and Jones (B. M.), geikielite and the ferro-magnesian titanates, 160.
Crystal-structure, 417.
Crystallization of sodium nitrate, 123.
— of potash-alum, 134.
— spontaneous, 123, 134.
— by inoculation, 123, 134.
— force of, 197.
Crystallographic projections, 99.
Crystals, thirty-two classes, 261, 360.
— irregular development, 43.
'Cullinan' diamond, 119.
Cumenge (E.), obituary, 65.
Curie (P.), obituary, 273.
Currie (J.), new localities for gyrolite and tobermorite, 98.
Cylindrite, analysis, 25.

D'Achiardi (A.), memorial volume, 68.
Day (A. L.), synthesis of minerals, 281.
Diamond, 'Cullinan,' from Premier mine, Transvaal, xxviii, 119.
Diopside from German East Africa, 179.
Domingite = jamesonite, 207.
Double salts, 321.
Drawing of crystals, 120.
Dufret (J. B. H.), obituary, 194.
Dundasite from Wales, 167.

'Economic Geology,' 196.
Enargite from Bolivia, 344.
Epidote, angles, 52.
— optical constants and chem. comp., 113.
— from Inverness-shire, 109.
Erubescite, formula of, 120.
Evans (J. W.), new forms of quartz-wedge, 87.
— identity of the amiantos or Karystian stone of the ancients with chrysotile, 143.
— gnomonic projection on two planes, 149.
— determination of optic axial angle in parallel light, 157.
— skiodroms and isogyres, 230.
— thirty-two classes of symmetry, 360.

Færöes, zeolites, 94, 419.
Feather-ore, 207.
Fichtelite, cryst., 197.
Fiedlerite, composition of, 121.
Fletcher (L.), meteoric irons from Great Namaqualand, 28.
— meteoric irons labelled 'Cape of Good Hope' and 'Great Fish River', 87.
— meteoric iron from Caperr, Patagonia, 41.
— obituary of H. P. Gurney, 61.
Fletcher (M.), cobaltiferous mispickel from Norway, 54.
Fluorite from Bolivia, 337.
Foster (C. Le N.), obituary, 57.
Fouqué (F. A.), obituary, 64.
Fowler (A.), spectroscopic determinations by, 384.
Franckeite, analysis, 24.

Geikielite analyses, 160.
— alteration products, 164.
German East Africa, phenacite, &c., 178.
Glauberite, pseudomorphs of opal after, 198.
Glimmerzeolith, 95, 409.
Gnomonic net, 18.
— projection, 104, 149.
Goniometer, three-circle, 1.
— signal, 4.
Goodchild (J. G.), obituary, 271.
Goodchild (W.), elected member, xxvii.
Grabham (G. W.), elected member, xix.
Great Fish River meteorite, 37.
Great Namaqualand, meteoric irons, 28.

Digitized by Google

Greenland, minerals of, 95, 195.
Greg (R. P.), obituary and portrait, 268.
Groth (P. von), 'Physikalische Krystallographie,' 195.
— testimonial to, portrait of, 66.
Growth, regular, of salts on each other, 235.
Guejarite from Bolivia, 322.
Gurney (H. P.), obituary, 61.
Gypsum crystals from chemical works, 211.
Gyrolite, new localities for, 93.

Hallowes (K. A. K.), apparatus for determining sp. gr. of grains, xxviii.
Hamlinite from Binn, 389.
Harrington (B. J.), formula of bornite, 121.
— isomorphism in magnetite, 373.
Hartley (H.), apparatus for separating minerals with heavy liquids, 69.
— microscopic heating stage, xxxvi.
— and Thomas (N. G.), pseudomorph of quartz after apophyllite from Tyrol, xxxvi.
Hatch (F. H.) and Corstorphine (G. S.), large diamond from Transvaal, xxviii, 119.
Heavy liquids, separating apparatus, 69.
Hemimorphite from Co. Tipperary, 351.
Hilton (H.), gnomonic net, 18.
— construction of crystallographic projections, 99.
— gnomonic projection, 104.
— thirty-two classes of symmetry, 261.
— brushes in convergent light, 281.
— elected member, xlii.
Hohmann (T.), collection, 309, 344.
Hopeite from Rhodesia, xliii.
Hornfels, tourmaline-, from Bolivia, 335.
Hudson (R. W. H. T.), obituary, 118.
Hutchinson (A.), mineralogical chemistry, 120.
— optical characters of antimonite, 199.
— chemical composition of lengenbachite, 204.
Hutchinsonite, 72, 284, 400.
Hyalophane from Binnenthal, 16, 190.

Iddings (J. P.), rock minerals, 416.
Identities, minerals, 121.
Ilmenite, magnesium, 165.
— from Binnenthal, 184.
Ilmenite, Brazil, 258.
Indices of faces, determination of, with moriogram, 49.
International Catalogue of Scientific Literature, xxii, xxviii, xxxv, xlii.
Irish minerals, 348, 350.
Iron-pyrites from Hungary, 68.
Ironstone, brookite, rutile, and anatase in, 96.
Isogyres and skiodroms, 159, 230, 276, 281.
Isomorphism in magnetite, 373.

Jade collection of H. R. Bishop, 419.
Jamesonite, chem. formula, 312.
— and feather-ore, 207.
— from Bolivia, 310.
Japanese minerals, 117, 120.
Jarosite from Bolivia, 342.
Jervis (W. P.), obituary, 418.
Johnston-Lavis (H. J.) and Spencer (L. J.), chlormanganokalite, xliii.
Jones (B. M.), elected member, xxxi.
— and Crook (T.), geikielite and the ferro-magnesian titanates, 160.
Judd (J. W.), obituary of C. Le N. Foster, 57.
— — F. Rutley, 59.

Kaolin from German East Africa, 179.
Karystian stone = chrysotile, 143.
Kylindrite, 25.

Labile and metastable solutions, 123, 134.
Laumontite from Binnenthal, 16.
Lead sulphantimonites, 210.
— sulpharsenites, 206.
Lengenbachite, 78, 204, 402.
Leucoxene, 164.
Lewis (W. J.), Pyroxene and albite, xxxiii.
Linarite from Co. Wicklow, 348.
Lindsey (C. R.), brookite in Cleveland ironstone, 96.
Lion River meteorite, 31, 34.
Localities of minerals, inconsistencies in statements of, 68.

McMahon (C. A.), obituary, 56.
Magnetite from Ross-shire, 119.
— titaniferous, from Canada and Arkansas, 373.
Marrite, 76, 188, 403.
Mears (J. B.), elected member, xli.
Members, list of, xi.
Metastable and labile solutions, 123, 134.
Meteoric irons from S. Africa, 28, 37.
— — Caperr, Patagonia, 41.

Digitized by Google

Miargyrite from Bolivia, 339, 340.
Mica mines in Canada, 196.
Micaceous zeolite, 95, 409.
Miers (H. A.), Kimberley diamond mines, xxiii.
— danalite from Cornwall, xxvii.
— barium-radium bromide, xxvii.
— experiments bearing on the order of crystallization of rock-constituents, xli.
— obituary of S. L. Penfield, 264.
— and Chevalier (J.), crystallization of sodium nitrate, 123.
Mineral-veins in Co. Tipperary, 350.
— Cornwall, 385.
Mineralogical chemistry, report of progress, 120.
Minerals, list of identities, 121.
— new names, 394.
Mispickel from Bolivia, 334.
— cobaltiferous, from Norway, 54.
Moissan (H.), obituary, 418.
Moissanite, 121, 404.
Moissenet (V. L.), obituary, 272.
Molecular volumes and parallel growth of crystals, 248.
Monoclinic-hemimorphic class, 197.
Moriogram, 49.
Morphotropic relations, 322.
Mukerop meteorite, 34.
Muscovite from German East Africa, 179.

Naegite, 117, 404.
Namaqualand, Great, meteoric irons, 28.

Obituaries :—
Behrens (T. H.), 118.
Brackebusch (L.), 418.
Chapman (E. J.), 65.
Cleve (P. T.), 194.
Cohen (E. W.), 194.
Cumenge (E.), 65.
Curie (P.), 273.
Dufret (J. B. H.), 194.
Foster (C. Le N.), 57.
Fouqué (F. A.), 64.
Goodchild (J. G.), 271.
Greg (R. P.), 268.
Gurney (H. P.), 61.
Hudson (R. W. H. T.), 118.
Jervis (W. P.), 418.
McMahon (C. A.), 56.
Moissan (H.), 418.
Moissenet (V. L.), 272.
O'Reilly (J. P.), 118.
Penfield (S. L.), 264.
Rutley (F.), 59.
Schmidt (S.), 65.
Obituaries (*continued*) :—
Soret (C.), 65.
Vorobjev (V. I.), 418.
Walker (J. F.), 418.
Ward (H. A.), 273.
Optic axial angle, determination of, from isogyres, 280.
— determination of, in parallel light, 157.
Optical characters of stibnite, 199.
Orange River district meteorite, 36.
O'Reilly (J. P.), obituary, 118.
Orpiment from Co. Tipperary, 352.
Orthoclase from German East Africa, 178.

Parallel growth of crystals, 235, 327.
Paratacamite, 170, 406.
Parkinson (J.), elected member, xli.
Pearce (R.), cassiterite pseudomorphs from Bolivia, 345.
Penfield (S. L.), elected hon. member, xxi.
— obituary and portrait, 264.
Peru, 'Boletin . . . de Minas,' 196.
Phenacite from Cornwall, xxviii.
— German East Africa, 178.
Picroilmenite from Ceylon, analyses, 165.
Plumosite, 207.
— from Bolivia, 315.
Polymorphism in zircon, 48.
Potash-alum, crystallization of, 134.
Potassium haloids and cyanide, 235.
Precious stones, cutting, 275.
Premier diamond mine, Transvaal, 119.
Prior (G. T.), Teallite, franckeite and cylindrite, 21.
— dundasite from Wales, 167.
— analyses by, 170, 308.
— and Smith (G. F. H.), red silver minerals from Binn, 283.
— and Solly (R. H.), zinciferous tennantite from Binn, xlii.
— and Zambonini (F.), strüverite, xlii.
Projections, crystallographic, 99.
— gnomonic, 18, 104, 149.
Proustite from Binnenthal, 189.
Pseudomorphous cassiterite from Bolivia, 345.
Pseudomorphs ('pine-apple') of opal, 197.
Pyrites, *see* iron-pyrites.
Pyrophyllite from Bolivia, 324, 335.
Pyrostilpnite from Bolivia, 328.
Pyroxene in serpentine-rock, 365.

Quartz-wedge, new forms of, 87.
— use of, 157.

Digitized by Google

Radium-barium bromide, cryst., xxvii.
Rashleigh collection, xxi.
Rastall (R. H.), elected member, xix.
Refractive index diagram, 191.
Refractometer, improved form, 83, 354.
Regular growth of soluble salts on each other, 235.
— tetrahedrite and stannite, 327.
Reinite, a pseudomorph, 117.
Reviews of books, 115, 275, 416.
Riebeckite from Ross-shire, 119.
Rock-forming minerals, 416.
— synthesis of, 281.
Rocks, chemical analysis of, 115.
— from Bolivia, 335.
Rosenbusch (H.), 419.
— 'Mikroskopische Physiographie,' 195.
Rubidium haloids and cyanide, 235.
Rudler (F. W.), handbook of British minerals, 116.
Russell (A.), linarite and caledonite in Co. Wicklow, 348.
— Silvermines district, Co. Tipperary, 350.
— new mineral localities in Cornwall and Devon, xxviii.
— exhibition of Cornish minerals, xxvii, xxviii, xxxiii, xxxix.
Rutile from alteration of geikielite, 164.
— in ironstone, 96, 98.
— from German East Africa, 178.
Rutley (F.), obituary, 59.

Sartorite from Binn, cryst., 212.
Schmidt (S.), obituary, 65.
Scotch minerals, 93, 109, 118.
Seligmannite, 82, 186.
Semseyite from Bolivia, 314.
Separating apparatus with heavy liquids, 69.
Serpentine-minerals, 368.
Serpentine-rock from Tarnthaler-Köpfe, Tirol, 365.
Silver-minerals from Binn, 283.
— Bolivia, 342.
Silver-ore in Cornwall, 385.
Skiodroms and isogyres, 230, 276.
Smith (G. F. H.), three-circle goniometer, 1.
— the moriogram, 49.
— improved form of refractometer, 83.
— paratacamite, a new oxychloride of copper, 170.
— determination of refractive indices, with diagram, 191.
— ilmenite from Brazil, 258.
— new model of refractometer, 354.
— obituary of R. P. Greg, 268.
Smith (G. F. H.), prismatic method of determining refractive indices, xxi.
— crystallographic determinations by, 184, 329, 331, 348.
— and Blake (G. S.), baddeleyite from Ceylon, 378.
— and Prior (G. T.), red silver minerals from Binn, 283.
Smithite, 74, 293, 409.
Smythe (J. A.), analysis by, 55.
Sodium haloids, 235.
Sodium nitrate, cystallization of, 123.
Solly (R. H.), anatase, &c., from Binn, 16.
— new minerals from Binn, 72.
— ilmenite, &c., from Binn, 184.
— the Lengenbach quarry, xxxix.
— and Prior (G. T.), zinciferous tennantite from Binn, xlii.
Sommerfeldt (E.), Physikalische Kristallographie, 417.
Soret (C.), obituary, 65.
South African meteorites, 28, 37.
Spencer (L. J.), zircon (sp. gr. 4.0) from Ceylon, 43.
— phenacite, &c., from German East Africa, 178.
— 'feather-ore'; identity of 'domingite' (= 'Warrenite') with jamesonite, 207.
— Bolivian minerals, jamesonite, tourmaline, &c., 308.
— list of new mineral names, 394.
— list of identities, 121.
— crystallographic determinations by, 345.
— pleochroism of adamite, xxi.
— and Johnston-Lavis (H. J.), chlormanganokalite, xliii.
Sphene from alteration of geikielite, 165.
Spherical triangles, solution of, with three-circle goniometer, 14.
Springbok River meteorite, 35.
Stannite, regular grouping with tetrahedrite, 327.
Stibnite, optical characters, 199.
— plumose, 208.
Story-Maskelyne (N. S.), letter to P. Groth, 66.
Symmetry, thirty-two classes of, 261, 360.
— axes of, 360.
Synthesis of rock-forming minerals, 281.

Tarbuttite, 411.
Teallite, 21, 411.
Tetrahedrite from Bolivia, 325.

Digitized by Google

Tetrahedrite, regular grouping with stannite, 327.
Textbooks, reviews, 115, 195, 416.
Thomas (H. H.), epidote from Inverness-shire, 109.
Three-circle goniometer, 1.
Tin-ores, Bolivian, 332, 345.
Tobermorite, new localities for, 93.
Topic axes and parallel growth of crystals, 253.
Tourmaline from Bolivia, 333.
— German East Africa, 178.
Tourmaline-hornfels from Bolivia, 335.
Trechmann (C. O.), crystallography of sartorite, 212.
Trechmannite, 75, 189, 300, 412.
Tremolite in serpentine-rock, 366.
Tschermak (G.), 419.

Valentinite from Bolivia, 328.
Vivianite from Bolivia, 324.
Vorobjev (V. I.), obituary, 418.

Wada (T.), minerals of Japan, 117.
Wada (T.), 'Beiträge zur Mineralogie von Japan,' 120.
Walker (J. F.), obituary, 418.
Ward (H. A.), obituary, 273.
Warrenite = jamesonite, 207.
Washington (H. S.), manual of the chemical analysis of rocks, 115.
Wild meteorite, 32.
Withamite from Glencoe, 119.
Wolframite from Bolivia, 334.
Woodgate (J.), elected member, xxv.
Woodward (C. J.), gypsum crystals from chemical works, 211.
Worobieff (V. von), obituary, 418.

Young (A. P.), serpentine-rock from Tarnthaler-Köpfe, Tirol, 365.

Zambonini (F.) and Prior (G. T.), strüverite, xlii.
Zircon, irregular crystals from Ceylon, 48.
— modifications of, 48.
Zonal growth of crystals, 252.
Zone-axes, 360.

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ERRATA.

VOL. VI.

PAGE.	LINE.	
xix (Proc.)		An original specimen in the British Museum collection of the supposed 'lead chromate' with the formula '$4PbO.3CrO_3$' has been proved to be vanadinite. The metallic zinc is of doubtful origin.

VOL. X.

iii (Proc.)	1	*For* 1892-3, *read* 1891-2.

VOL. XI.

283	22	*For* Magnetite after Cerussite *read* Malachite after Cerussite.

VOL. XII.

13	17	*For* L. F. Navarro, *read* L. Fernández Navarro.
13 (footnote 2)		*For* Espanola, *read* Española.
98	9	*For* total percentage in the mineral, *read* total percentage of titanic acid in the mineral.
244	10*	*For* Rio Tequetinhonha, *read* Rio Jequitinhonha.
389	13*	*For* P. Groth, &c., *read* E. Hussak, Min. Petr. Mitt. (Tschermak), 1895. vol. xiv, p. 408.

VOL. XIII.

303	20	*For* (1831-1901), *read* (1831-1906).
364	17	*For* snow-white scales, *read* snow-white tufts. (See L. Brugnatelli, Centralblatt Min., 1903, p. 663.)

VOL. XIV.

29	5	*For* Milman, *read* Wilman.
184	—	The table of angles belongs to the first footnote.
201	21	*For* perpendicular to *c* (001), *read* parallel to *c* (001).
202	17	*For* optic axis, *read* optic axes.

* From bottom of page.

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442

MINERALOGICAL SOCIETY.

(*Instituted February* 3, 1876.)

BYE-LAWS.

1. The object of the Mineralogical Society of Great Britain and Ireland, with which the Crystallological Society was amalgamated on December 11, 1888, shall be to advance the knowledge of Mineralogy, and also of Crystallography and Petrology.

2. The Society shall consist of Ordinary Members and Honorary Members.

Ordinary Members.

3. Every candidate for Ordinary Membership shall be proposed by two Ordinary Members, one, at least, of whom shall have personal knowledge of the candidate.

4. Elections to Ordinary Membership shall be made by the Council, and shall be confirmed at the ensuing general meeting by a majority consisting of three-fourths of the Members present and voting.

5. Ordinary Members shall pay an entrance fee of one guinea and an annual subscription of one guinea. Ordinary Members elected on or before November 13, 1900, shall be entitled to compound for the annual subscription by a single payment of ten guineas: Ordinary Members elected after that date shall be entitled to compound for the annual subscription by a single payment of fifteen guineas.

6. Annual Subscriptions shall be due on the first of January of each year, but Members elected after the first of October shall not be required to pay a subscription for the then current year.

7. The name of any Ordinary Member whose subscription is more than two years in arrear shall be brought before the Council, and an intimation that this action has been taken shall be communicated to the Member. After the expiration of at least one year from that date, the Council shall be empowered to erase the name from the List of Members.

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Honorary Members.

8. Twenty persons, non-resident in the United Kingdom, may be elected Honorary Members. They shall pay neither entrance fee nor annual subscription.

9. Every candidate for Honorary Membership shall be proposed by two Members of the Council, and the election shall be by the Council, and shall be confirmed at the ensuing general meeting by a majority consisting of three-fourths of the Members present and voting.

Council.

10. The Society shall be governed by a Council, consisting of a President, two Vice-Presidents, a General Secretary, a Foreign Secretary, a Treasurer, an Editor of the Journal, and twelve Ordinary Members.

11. All members of the Society who have served the office of President shall be life-members of the Council.

12. The Council shall be elected annually at the Anniversary Meeting.

13. Four Ordinary Members of Council shall retire annually, and shall not be eligible for re-election until the next Anniversary Meeting.

14. The Council shall prepare a List of Members nominated for election as Officers and Ordinary Members of Council.

15. The election of Council shall be effected by the agency of voting papers containing the List nominated by the Council. They shall be sent by the General Secretary, at least four weeks before the Anniversary Meeting, to every Ordinary Member of the Society, and every such Member shall be entitled to substitute the names of any other Ordinary Members of the Society for those on the List.

16. The voting papers shall be returned by the Members to the General Secretary, and shall be examined at the Anniversary Meeting by two Scrutineers appointed by the Chairman, who shall on their report declare the result of the election. The voting papers need not be signed.

17. The Council shall have power to appoint Officers, and to co-opt Ordinary Members of Council, to fill vacancies in the Council caused by death or resignation during the interval between two Anniversary Meetings.

18. Meetings of the Council shall be summoned by order of the President or the Council; at such meetings three shall be a quorum, of whom

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one shall be either the President, a Vice-President, the Treasurer, or the General Secretary.

19. A Report of Council on the work and progress of the Society shall be submitted at each Anniversary Meeting.

Trustees.

20. Two or more Trustees shall be appointed by the Council, and the invested property of the Society shall stand in their names.

21. Composition-fees shall be treated as Capital: a Resolution of the Society at a general meeting, summoned with notice of a proposed disposition of property, shall be sufficient authority to the Trustees to give effect to such disposition; provided that a resolution of the Council shall be sufficient authority for any change of investment.

Meetings.

22. Meetings of the Society shall be summoned from time to time, as may be deemed necessary by the Council, or at the requisition of any ten Members of the Society. One of these meetings in each year shall be termed the Anniversary Meeting.

Journal.

23. The Numbers of the *Mineralogical Magazine and Journal of the Society* shall be issued at such intervals as the Council shall determine, and shall be sent, postage paid, to every Member of the Society.

Auditors and Balance Sheet.

24. Two Ordinary Members of the Society, one of whom is not a Member of the Council, shall be appointed annually by the Council to audit the accounts of the Society.

25. No auditor shall serve for more than three years in succession.

26. The audited Balance-Sheet, after submission to the Council, shall be published in the Journal of the Society as early as possible in every year.

Expulsion of Members.

27. A majority consisting of three-fourths of the whole Council shall have power to expel a Member from the Society, but a Member who has been expelled shall have a right of appeal to the Society. Notice of such appeal to the Society shall be sent by such Member to the General Secretary within four weeks of the expulsion, and the appeal shall be considered by the Society at the next Anniversary Meeting; a

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majority of the votes recorded at such Meeting sufficing to confirm or annul the decision of the Council.

Alteration of the Bye-Laws.

28. The Bye-laws may be altered only at an Anniversary Meeting, and only by a majority consisting of three-fourths of the Members present and voting. Notice of changes proposed to be made in the Bye-laws shall be communicated by the General Secretary to every Ordinary Member of the Society at least four weeks before the Anniversary Meeting at which they are to be considered.

Obligation Book.

29. Ordinary Members, by payment of their entrance fee, signify their acceptance of any Bye-laws approved by the Society; and every Member of the Society shall sign an Obligation Book.

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LIST OF MEMBERS.

(*September*, 1904.)

HONORARY MEMBERS.

M. E. Bertrand, *Paris.*
Dr. A. Brezina, *Vienna.*
Prof. W. C. Brögger, *Christiania.*
Prof. G. J. Brush, *New Haven, U.S.A.*
Prof. E. S. Dana, *New Haven, U.S.A.*
Prof. P. von Groth, *Munich.*
Prof. C. Klein, *Berlin.*
Prof. A. Lacroix, *Paris.*
Prof. V. von Lang, *Vienna.*
M. A. Michel Lévy, *Paris.*
Prof. T. Liebisch, *Göttingen.*
Prof. E. Ludwig, *Vienna.*
Prof. S. L. Penfield, *New Haven, U.S.A.*
Prof. H. Rosenbusch, *Heidelberg.*
Dr. K. J. V. Steenstrup, *Copenhagen.*
Prof. G. Strüver, *Rome.*
Prof. G. Tschermak, *Vienna.*
Prof. F. J. Wiik, *Helsingfors.*
Prof. F. Zirkel, *Leipzig.*

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ORDINARY MEMBERS[1].

A. Annual Subscribers.

L. Life-Members.

C. Belonged to the Crystallological Society at the time of the amalgamation of the two Societies, December 11, 1888.

Year of Election.

L 1888 ARNOLD-BEMROSE, Henry Howe, M.A., F.G.S. *Ash Tree House, Osmaston Road, Derby.*

A 1881 BAKER, Harry, F.C.S. *Epworth House, Maughland Lane, Runcorn, Cheshire.*

L 1894 BARLOW, William, F.G.S., F.C.S. *The Red House, Stanmore, Middlesex.*

L 1876 BARNETT, A. K., F.G.S. 11 *Penrose Terrace, Penzance, Cornwall.*

L 1893 BARROW, George, F.G.S. Geological Survey of England. *The Museum, 28 Jermyn Street, London, S.W.*

L 1897 BEALE, William Phipson, K.C., F.G.S., F.C.S. 10 *New Court, Carey Street, London, W.C.*

A 1894 BERINGER, John J., A.R.S.M., F.C.S. *School of Mines, Camborne, Cornwall.*

A 1894 BERKELEY, The Rt. Hon. the Earl of, F.G.S., F.C.S. *Foxcombe, Boar's Hill, near Oxford.*

L 1876 BONNEY, Rev. Thomas George, D.Sc., LL.D., F.R.S. Emeritus Professor of Geology in University College, London. 23 *Denning Road, Hampstead, London, N.W.*

L 1897 BOWMAN, Herbert Lister, M.A., F.C.S. *Mineral Department, The Museum, Oxford.*

L 1876 BROWN, Alexander Crum, M.D., D.Sc., F.R.S. Professor of Chemistry in the University of Edinburgh. 8 *Belgrave Terrace, Edinburgh.*

A 1901 BURLS, Herbert Thomas, F.G.S. *Brunswick House,* 84 *Lee Road, Blackheath, London, S.E.*

L 1885 BUTLER, Francis Henry, M.A., A.R.S.M. 158 *Brompton Road, London, S.W.*

[1] Corrections for this List should be sent to the General Secretary, 35 Woodville Gardens, Ealing, London, W.

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Year of Election.

A 1889 **Butler**, William Waters, F.C.S. *Southfield, Norfolk Road, Edgbaston, Birmingham.*

A 1903 **Campbell**, Donald Fraser, B.A., F.G.S. 86 *Oakley Crescent, Chelsea, London, S.W.*

A 1876 **Church**, Arthur Herbert, M.A., D.Sc., F.R.S. Professor of Chemistry in the Royal Academy of Arts. *Shelsley, Ennerdale Road, Kew, Surrey.*

A 1888 **Cole**, Grenville A. J., M.R.I.A., F.G.S. Professor of Geology in the *Royal College of Science, Dublin.*

L 1892 **Collins**, Henry F., A.R.S.M. 702 *Salisbury House, Finsbury Circus, London, E.C.*

L 1876 **Collins**, Joseph Henry, F.G.S. *Crinnis House, Par Station, Cornwall.*

L 1900 **Coomáraswámy**, Ananda K., B.Sc., F.L.S., F.G.S. Director of the Mineral Survey of Ceylon. *Kandy, Ceylon.*

L 1888 **Crookes**, Sir William, D.Sc., F.R.S. 7 *Kensington Park Gardens, London, W.*

A 1899 **Cullis**, Charles Gilbert, D.Sc., F.G.S. Assistant-Professor of Geology in the *Royal College of Science, South Kensington, London, S.W.*

L 1899 **Currie**, James, M.A., F.R.S.E. *Larkfield, Golden Acre, Edinburgh.*

L 1876 **Danby**, Thomas William, M.A., F.G.S. *The Crouch, Seaford, Sussex.*

L 1885 **Daw**, John W., 4 *Gunnersbury Avenue, Ealing, London, W.*

L 1898 **De Castro**, J. Paul, M.A., F.C.S., F.I.C. 1 *Arundel Street, Strand, London, W.C.*

L 1891 **Evans**, John William, LL.B., D.Sc., F.G.S. 75 *Craven Park Road, Willesden Junction, London, N.W.*

L 1900 **Fleischmann**, Friedrich Noel Ashcroft, M.A., F.C.S. 6 *Collingham Gardens, London, S.W.*

L C **Fletcher**, Lazarus, M.A., F.R.S. Keeper of Minerals in the British Museum (Natural History), Cromwell Road, London, S.W. 35 *Woodville Gardens, Ealing, London, W.*

L 1895 **Fletcher**, Rev. Mark, M.A., F.G.S. Demonstrator in Mineralogy in the Durham College of Science. *The Vicarage, North Sunderland, Chathill R.S.O., Northumberland.*

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Year of Election.

A 1902 FLETT, John Smith, M.A., D.Sc., F.R.S.E., F.G.S. Geological Survey of England. *The Museum, 28 Jermyn Street, London, S.W.*

A 1876 GEIKIE, Sir Archibald, D.Sc., D.C.L., LL.D., F.R.S. Formerly Director-General of the Geological Surveys of the United Kingdom. 10 *Chester Terrace, Regent's Park, London, N.W.*

A 1876 GEIKIE, James, LL.D., D.C.L., F.R.S. Professor of Geology and Mineralogy in the University of Edinburgh. *Kilmorie, Colinton Road, Edinburgh.*

L 1881 GIBB, T. J., 37 *Old Jewry, London, E.C.*

L 1902 GILES, William B., F.I.C. *The Grange, Leyton, Essex.*

L 1886 GOLDSCHMIDT, Dr. Victor, Professor of Mineralogy in the University of Heidelberg. 9 *Gaisbergstrasse, Heidelberg, Germany.*

A 1895 GORDON, Rev. John More, F.G.S. *St. John's Vicarage, Redhill, Surrey.*

A 1903 GRABHAM, George Walter, B.A., F.G.S. Geological Survey of England. *The Museum, 28 Jermyn Street, London, S.W.*

L 1892 GREGORY, John Walter, D.Sc., F.R.S. Professor of Geology in the *University of Glasgow.*

A 1900 HALL, Arthur Lewis, B.A., F.G.S. *Geological Survey Office, Box 418, Pretoria, Transvaal.*

A 1885 HARKER, Alfred, M.A., F.R.S. Fellow of St. John's College, Cambridge. Geological Survey of Scotland. *St. John's College, Cambridge.*

L 1900 HARTLEY, Harold Brewer, B.A., F.C.S. *Balliol College, Oxford.*

A 1879 HENSON, Samuel, 97 *Regent Street, London, W.*

A 1888 HOFFMANN, G. Christian, LL.D. *Geological Survey Office, Sussex Street, Ottawa, Canada.*

L 1896 HOLLAND, Thomas Henry, A.R.C.S., F.R.S. Director of the Geological Survey of India. *Geological Survey Office, Calcutta, India.*

A 1879 HORNE, John, LL.D., F.R.S. Geological Survey of Scotland. *Geological Survey Office, Sheriff's Court Buildings, Edinburgh.*

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Year of Election.

A 1902 HOWE, John Allen, B.Sc., F.G.S. Curator of the Museum of Practical Geology. *The Museum, 28 Jermyn Street, London, S.W.*

A 1876 HUDLESTON, Wilfrid Hudleston, M.A., F.R.S. 8 *Stanhope Gardens, South Kensington, London, S.W.*

A 1878 HUGHES, Thomas McKenny, M.A., F.R.S. Professor of Geology in the University of Cambridge. *Ravensworth, Brooklands Avenue, Cambridge.*

A 1893 HUSSAK, Dr. Eugen. *Commissão Geographica e Geologica de S. Paulo, Brazil.*

L 1890 HUTCHINSON, Arthur, M.A., Ph.D., F.C.S., F.G.S. Demonstrator of Mineralogy in the University of Cambridge. *Pembroke College, Cambridge.*

A 1899 JACKSON, Henry, M.A., B.Sc., F.C.S. *Downing College, Cambridge.*

A 1902 JEVONS, Herbert Stanley, M.A., D.Sc., F.G.S. Lecturer in Mineralogy and Petrology in the *University of Sydney, New South Wales.*

L 1884 JUDD, John Wesley, C.B., LL.D., F.R.S. Professor of Geology in, and Dean of, the Royal College of Science, South Kensington, S.W. 22 *Cumberland Road, Kew, Surrey.*

L 1876 KINCH, Edward, F.C.S. Professor of Chemistry in the *Royal Agricultural College, Cirencester.*

L 1876 KITTO, Benedict, F.I.C., F.G.S. 26 *Lancaster Road, Finsbury Park, London, N.*

A 1885 KUNZ, George Frederick, M.A., Ph.D. *Care of Messrs. Tiffany & Co., Union Square, New York City, U.S.A.*

A C LEWIS, William James, M.A., F.C.S. Professor of Mineralogy in the University of Cambridge. *The New Museums, Cambridge.*

A 1886 LINDSEY, C. R., B.Sc. 11 *Brantingham Road, Whalley Range, Manchester.*

L C LIVEING, George Downing, M.A., D.Sc., F.R.S. Professor of Chemistry in the University of Cambridge. *Newnham, Cambridge.*

L 1876 LIVERSIDGE, Archibald, M.A., LL.D., F.R.S. Professor of Chemistry in the *University of Sydney, New South Wales.*

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Year of Election.

A 1879 Louis, Henry, M.A., A.R.S.M., F.G.S. Professor of Mining in the *Durham College of Science, Newcastle-on-Tyne.*

A 1902 McGrigor, George Duncan, F.R.G.S. 25 *Charles Street, St. James's, London, S.W.*

A 1902 Maitland, Andrew Gibb, C.E., F.G.S. Government Geologist. *Geological Survey, Perth, Western Australia.*

L 1881 Mallet, Frederick Richard, F.G.S., F.C.S. 20 *King's Avenue, Ealing, London, W.*

A 1902 Mennell, Frederic Philip, F.G.S. Curator of the *Rhodesia Museum, Bulawayo, Rhodesia.*

L 1876 Merry, J. S., *Swansea, South Wales.*

L C Miers, Henry Alexander, M.A., D.Sc., F.R.S. Professor of Mineralogy in the University of Oxford. *Magdalen College, Oxford.*

L 1876 Morris, James, 6 *Windsor Street, Swansea, South Wales.*

A C Müller, Hugo, Ph.D., LL.D., F.R.S. 13 *Park Square East, Regent's Park, London, N.W.*

L 1880 Pearce, Richard, F.G.S. *Denver City, Colorado, U.S.A.*

L 1899 Pollard, William, M.A., D.Sc., F.G.S. Geological Survey of England. *The Museum,* 28 *Jermyn Street, London, S.W.*

A 1891 Pope, William Jackson, F.R.S. Professor of Chemistry in the Municipal School of Technology, Manchester. 16 *Hope Street, Higher Broughton, Manchester.*

A 1887 Pringle, A., M.A., B.Sc. Assistant Curator, Museum of Practical Geology. *The Museum,* 28 *Jermyn Street, London, S.W.*

L 1887 Prior, George Thurland, M.A., F.G.S. *British Museum (Natural History), Cromwell Road, London, S.W.*

A 1903 Rastall, Robert Heron, B.A., F.G.S. *Christ's College, Cambridge.*

A 1876 Rudler, Frederick William, F.G.S. 18 *St. George's Road, Kilburn, London, N.W.*

A 1902 Russell, Arthur Edward Ian Montagu. *Swallowfield Park, Reading.*

L 1876 Scott, Robert Henry, M.A., D.Sc., F.R.S. 6 *Elm Park Gardens, London, S.W.*

A 1903 Scrivenor, John Brooke, M.A., F.G.S. Geologist to the Federated Malay States. *Kuala Lumpur, Federated Malay States.*

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Year of Election.

A 1884 SELIGMANN, Gustav, 18 *Schlossrondel, Coblenz, Rhenish Prussia.*

L 1897 SMITH, George Frederick Herbert, M.A., F.G.S., F.R.A.S. *British Museum (Natural History), Cromwell Road, London, S.W.*

A 1897 SOLLAS, William Johnson, M.A., D.Sc., LL.D., F.R.S. Professor of Geology in the University of Oxford. *The Museum, Oxford.*

A C SOLLY, Richard Harrison, M.A., F.G.S. *Downing College, Cambridge.*

L 1876 SORBY, Henry Clifton, LL.D., F.R.S. *Broomfield, Sheffield.*

A 1894 SPENCER, Leonard James, M.A., F.G.S. *British Museum (Natural History), Cromwell Road, London, S.W.*

A 1878 SPEZIA, Giorgio, Professor of Mineralogy in the *University, Turin, Italy.*

A C STORY-MASKELYNE, Mervin Herbert Nevil, M.A., D.Sc., F.R.S. Late Professor of Mineralogy in the University of Oxford. *Basset Down House, Swindon, Wilts.*

A 1883 TEALL, J. J. Harris, M.A., D.Sc., F.R.S. Director of the Geological Survey of the United Kingdom and of the Museum of Practical Geology. *The Museum, 28 Jermyn Street, London, S.W.*

A 1903 THOMAS, Herbert Henry, B.A., F.G.S. Geological Survey of England. *The Museum, 28 Jermyn Street, London, S.W.*

L 1877 TRECHMANN, Charles O., J.P., Ph.D., F.G.S. *Hudworth Tower, Castle Eden, Co. Durham.*

A 1891 TUTTON, Alfred Edwin Howard, D.Sc., A.R.C.S., F.R.S. 17 *Bardwell Road, Oxford.*

A 1876 WALKER, John Francis, M.A., F.G.S., F.L.S., F.C.S. 45 *Bootham, York.*

L 1894 WATTS, William Whitehead, M.A., F.R.S. Assistant Professor of Geology, University of Birmingham. *Holmwood, Bracebridge Road, Four Oaks, Sutton Coldfield, Warwickshire.*

L 1895 WEBB, R. C.

L 1901 WESTON, Digby, St. A. P., Lieutenant R.N., *H.M.S. Albion, China Station.*

L 1876 WILLS, J. Lainson, F.C.S. *Care of Dr. F. Wyatt, 39 South William Street, New York City, U.S.A.*

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Year of Election.

L 1896 WILLS, Louis.

A 1889 WOODWARD, Bernard Henry, F.G.S. *The Museum, Perth, Western Australia.*

L C WOODWARD, Charles J., B.Sc., F.G.S. Birmingham Municipal Technical School. 127 *Metchley Lane, Harborne, Birmingham.*

A 1897 WOOLLETT, N. E.

A 1902 YOUNG, Alfred Prentice, Ph.D., F.G.S. *Care of Messrs. Grindlay & Co., 55 Parliament Street, London, S.W.*

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PROCEEDINGS

OF THE

MINERALOGICAL SOCIETY.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, November 17, 1903.

Dr. Hugo Müller, F.R.S., President, in the Chair.

The following Candidates were elected Ordinary Members of the Society:—Mr. Donald Fraser Campbell, B.A.; Mr. George Walter Grabham, B.A.; and Mr. Robert Heron Rastall, B.A.

The death of Professor A. F. Renard, Honorary Member of the Society, was announced, and the Foreign Secretary was requested to send a letter of condolence to the widow.

The following were selected as dates of meeting for 1904:—February 2, March 22, June 7, November 15, the last to be the Anniversary Meeting.

The draft Annual Report of Council, submitted by the Secretary, was read and approved.

ANNIVERSARY MEETING.

Held in the Apartments of the Geological Society, November 17, 1903.

Dr. Hugo Müller, F.R.S., President, in the Chair.

Twenty-three Members were present.

The scrutineers reported that thirty-nine voting papers had been returned to the General Secretary, and that the List as nominated by the Council was approved, namely:—

President. Hugo Müller, Esq., Ph.D., LL.D., F.R.S.

Vice-Presidents. Prof. G. D. Liveing, M.A., D.Sc., F.R.S.
Prof. H. A. Miers, M.A., D.Sc., F.R.S.

Treasurer. W. Phipson Beale, Esq., K.C., F.G.S., F.C.S.

General Secretary. L. Fletcher, Esq., M.A., F.R.S.

Foreign Secretary. Prof. J. W. Judd, C.B., LL.D., F.R.S.

Editor of the Journal. L. J. Spencer, Esq., M.A., F.G.S.

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Ordinary Members of Council.

W. Barlow, Esq., F.G.S., F.C.S.
B. Kitto, Esq., F.I.C., F.G.S.
F. W. Rudler, Esq., F.G.S.
G. F. Herbert Smith, Esq., M.A., F.G.S.
A. Harker, Esq., M.A., F.R.S.
Lieut.-Gen. C. A. McMahon, F.R.S.
W. Pollard, Esq., M.A., D.Sc., F.G.S.
G. T. Prior, Esq., M.A., F.G.S.
H. L. Bowman, Esq., M.A., F.C.S.
H. F. Collins, Esq., A.R.S.M.
C. G. Cullis, Esq., D.Sc., F.G.S.
R. H. Solly, Esq., M.A., F.G.S.

The following Annual Report of Council was read:—

The Balance Sheet for the year ending December 31, 1902, shows that the Assets of the Society (exclusive of the Library and the Stock of the Journal) amounted to £623 10*s.* 7*d.*, and that the Liabilities amounted to £18 11*s.* 3*d.* The number of Life-Members on December 31, 1902, was fifty-two; the value of the Stock invested in the names of the Trustees of the Society was on that date £508 7*s.* 6*d.*

During the Session 1902–3 the Society has lost by death two Ordinary and two Honorary Members; on the other hand, eight Ordinary Members have been elected, and Professor Liebisch, of Göttingen, and Professor G. Strüver, of Rome, have been added to the list of Honorary Members. The total number of Members is now 126; of these 107 are Ordinary Members and nineteen are Honorary Members.

Four meetings have been held during the year, all in London and (by kind permission) in the Apartments of the Geological Society, Burlington House.

One Number of the Journal, No. 61, published in February, 1903, has appeared during the Session.

The Council has to congratulate the Society on its continued prosperity.

On the motion of Professor H. A. Miers, seconded by Mr. H. L. Bowman, the Report was adopted. A vote of thanks to the Geological Society for the permission to meet in its Apartments was carried with acclamation.

The elections of Mr. D. F. Campbell, Mr. G. W. Grabham, and Mr. R. H. Rastall to the Ordinary Membership of the Society were confirmed.

The following papers were then read:—

1. On Sartorite, Anatase, Galena, and other minerals from the Binnenthal: by Mr. R. H. Solly (p. 16).

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2. On the pleochroism of Adamite: by Mr. L. J. Spencer.

3. On the prismatic method of determining refractive indices: by Mr. G. F. Herbert Smith.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, February 2, 1904.

Dr. Hugo Müller, F.R.S., President, in the Chair.

The resignation of Mr. S. R. Adcock was accepted.

Mr. J. H. Collins and Mr. H. L. Bowman were appointed to audit the accounts of the Society.

Professor S. L. Penfield, of Yale University, was elected an Honorary Member.

GENERAL MEETING.

Held in the Apartments of the Geological Society, February 2, 1904.

Dr. Hugo Müller, F.R.S., President, in the Chair.

Twenty-two Members and three Visitors were present.

The election of Professor S. L. Penfield, Yale University, to the Honorary Membership was confirmed.

The following papers were read:—

1. The Gnomonic Net: by Mr. Harold Hilton (p. 18).

2. On a new sulphostannite of lead (Teallite), from Bolivia, and its relations to Franckeite and Cylindrite: by Mr. G. T. Prior (p. 21).

Mr. W. F. Ferrier then gave a short account of the discovery of Corundum in Canada and its mode of occurrence in that region.

Professor H. A. Miers, followed by Mr. W. F. Ferrier, Mr. L. J. Spencer, and Mr. J. H. Collins, called the attention of the members to the exhibition of the Rashleigh Mineral Collection in the Truro Museum, specially mentioning the Connellite, Cassiterite, Clinoclase, and Erubescite.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, March 22, 1904.

Dr. R. H. Scott, F.R.S., Past-President, in the Chair.

The Secretary announced the deaths of Professor Ferdinand Fouqué, Honorary Member, and Lieut.-Gen. C. A. McMahon, Ordinary Member.

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The audited Balance Sheet for the year ending December 31, 1903, was submitted and approved.

It was reported that Mr. L. J. Spencer had sent in to the Central Bureau of the International Catalogue of Scientific Literature 535 slips relative to titles of mineralogical papers published in Great Britain during 1903.

GENERAL MEETING.

Held in the Apartments of the Geological Society, March 22, 1904.

Professor H. A. Miers, F.R.S., Vice-President, in the Chair.

Nineteen Members were present.

The following papers were read:—

1. Irregularly developed crystals of Zircon (specific gravity 4·0) from Ceylon: by Mr. L. J. Spencer (p. 43).

2. Notes on 'Feather-ore': identity of 'Domingite' (= 'Warrenite') with Jamesonite: by Mr. L. J. Spencer.

3. Further determinations of the indices of refraction of Stibnite from Japan: by Dr. A. Hutchinson.

4. The connexion between the atom-arrangements of the crystals of certain allied carbon compounds: by Mr. W. Barlow.

5. On the construction and use of a diagram in connexion with the anharmonic ratios of four tautozonal planes: by Mr. Herbert Smith (p. 49).

6. Note relative to the history of the Caperr meteorite: by Mr. L. Fletcher (p. 41).

7. On the meteoric irons of Bethany, Lion River, Mukerop, Springbok River, and Great Fish River, South Africa: by Mr. L. Fletcher (pp. 28, 37).

Further Professor Judd called attention to two twins of Quartz from La Gardette, which he submitted for inspection.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, June 7, 1904.

Dr. Hugo Müller, F.R.S., President, in the Chair.

The Secretary announced the deaths of Professor Sir Clement Le Neve Foster, Mr. Frank Rutley, and Mr. Hamilton Charles Dickson, and the ›n of Mr. William Rich, Ordinary Members of the Society.

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Resolved to nominate as Officers and Council for the Session 1904–5, the following:—

President. Professor H. A. Miers (*vice* Dr. Hugo Müller).

Vice-President. Professor W. J. Lewis (*vice* Professor H. A. Miers); and Dr. J. W. Evans, the Rev. J. More Gordon, Mr. J. Allen Howe, and Dr. A. Hutchinson in place of Messrs. Barlow, Kitto, Rudler, and McMahon, Ordinary Members of Council; the remainder of the Officers and Council to be the same as at present.

GENERAL MEETING.

Held in the Apartments of the Geological Society, June 7, 1904.

Dr. Hugo Müller, F.R.S., President, in the Chair.

Sixteen Members and two Visitors were present.

A photogravure of the portrait of Professor Groth was submitted for inspection (p. 66).

The following papers were read:—

1. On cobaltiferous Mispickel from Norway: by the Rev. Mark Fletcher (p. 54).

2. On an improved form of Refractometer: by G. F. Herbert Smith.

3. Notes on the Development of the Kimberley Diamond Mines: by Professor H. A. Miers.

Professor Miers' notes were accompanied with numerous lantern illustrations.

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MINERALOGICAL SOCIETY.

ABSTRACT OF RECEIPTS AND PAYMENTS FROM JANUARY 1 TO DECEMBER 31, 1903.

Receipts.	£ s. d.	£ s. d.
Balance from 1902		90 15 0
Subscriptions—(1) current	40 19 0	
(2) arrears	9 9 0	
(3) in advance	3 3 0	
		53 11 0
Entrance fees and compositions		22 1 0
Sales of publications by publishers (1902)	11 11 6	
Do. by G. Savigar (1902)	1 5 7	
		12 17 1
Dividends on Stock		14 12 5
Donation towards Illustrations		5 13 6
Overpayment of foreign subscriptions		0 2 0
		£199 12 0

Payments.	£ s. d.	£ s. d.
Printing Magazine (No. 61)	35 5 10	
Authors' separate copies	5 11 9	
Illustrations (Printers)	10 16 6	
„ (Miss Drake)	2 2 0	
		53 16 1
Miscellaneous Printing		8 8 7
Editor's Honorarium (1902)		10 10 0
Postage and Parcels		2 8 10
G. Savigar for care of stock (1902)		1 1 0
Porter's Fee		1 0 0
Bank Charges		6 0
Investments		67 2 5
Balance at Bank	50 16 5	
„ in Office	4 7 8	
		55 4 1
		199 12 0

Examined and compared with the vouchers, and found correct.

(*Signed*) J. H. COLLINS. H. L. BOWMAN. } Auditors.

Liabilities.	£ s. d.
Owing for Printing, &c., of No. 62 of Magazine	51 7 1
„ Editor's Honorarium (1903)	10 10 0
„ Miscellaneous Printing	4 14 10
„ G. Savigar for care of Stock (1903)	1 1 0
„ Do. for postage	0 1 4
„ Secretary's postage (1903)	0 17 8
„ Treasurer's „ (1903)	0 8 10
Excess of assets over liabilities	556 9 9
	£625 10 6

Assets.	£ s. d.
Balance at Bank	50 16 5
„ in Office	4 7 8
Consols (£629 6*s.* 1*d.*, valued at £87)	547 9 10
Balance owing from Publishers	12 16 0
„ „ „ G. Savigar	0 11 7
Subscriptions in arrear, valued at	9 9 0
	£625 10 6

The number of Life-Members on December 31, 1903, was 52.

The Stock of Publications and the value of the Library are not included in the above assets.

(*Signed*) W. P. BEALE,
Hon. Treasurer.

March, 1904.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, November 15, 1904.

Dr. Hugo Müller, F.R.S., President, in the Chair.

The death of Dr. Henry P. Gurney, Ordinary Member of the Society, was announced.

The following Candidates were elected Ordinary Members of the Society:—Mr. Thomas Vipond Barker, B.A., and Mr. John Woodgate, M.I.M.M.

ANNIVERSARY MEETING.

Held in the Apartments of the Geological Society, November 15, 1904.

Dr. Hugo Müller, F.R.S., President, in the Chair.

Twenty-two Members were present.

The elections of Mr. T. V. Barker and Mr. J. Woodgate to the Ordinary Membership of the Society were confirmed.

The scrutineers reported that thirty-eight voting papers for the election of Officers and Council had been returned to the General Secretary, and that the List as nominated by the Council was approved, namely:—

President. Prof. H. A. Miers, M.A., D.Sc., F.R.S.

Vice-Presidents. Prof. W. J. Lewis, M.A., F.C.S.
Prof. G. D. Liveing, M.A., D.Sc., F.R.S.

Treasurer. W. Phipson Beale, Esq., K.C., F.G.S., F.C.S.

General Secretary. L. Fletcher, Esq., M.A., F.R.S.

Foreign Secretary. Prof. J. W. Judd, C.B., LL.D., F.R.S.

Editor of the Journal. L. J. Spencer, Esq., M.A., F.G.S.

Ordinary Members of the Council.

G. F. Herbert Smith, Esq., M.A., F.G.S.
A. Harker, Esq., M.A., F.R.S.
W. Pollard, Esq., M.A., D.Sc., F.G.S.
G. T. Prior, Esq., M.A., F.G.S.
H. L. Bowman, Esq., M.A., F.C.S.
H. F. Collins, Esq., A.R.S.M.
C. G. Cullis, Esq., D.Sc., F.G.S.
R. H. Solly, Esq., M.A., F.G.S.
J. W. Evans, Esq., LL.B., D.Sc., F.G.S.
The Rev. J. M. Gordon, F.G.S.
J. A. Howe, Esq., B.Sc., F.G.S.
A. Hutchinson, Esq., M.A., Ph.D., F.G.S.

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The following ANNUAL REPORT OF COUNCIL was read:—

The Balance Sheet for the year ending December 31, 1903, which has already been published in No. 63 of the Journal, shows that the Assets of the Society (exclusive of the Library and the Stock of the Journal) amounted to £625 10*s.* 6*d.*, and that the Liabilities amounted to £69 0*s.* 9*d.*

The number of Life-Members on December 31, 1903, was fifty-two; the value of the Stock invested in the names of the Trustees of the Society was on that date £547 9*s.* 10*d.*, corresponding to £10 10*s.* 7*d.* for each Life-Member.

During the Session 1903–4 the Society has lost by death five Ordinary Members (Mr. Dickson, Professor Le Neve Foster, Dr. Gurney, General McMahon, and Mr. Rutley) and two by resignation (Mr. Adcock and Mr. Rich); one Honorary Member (Professor Fouqué) has died. On the other hand, three Ordinary Members (Mr. Campbell, Mr. Grabham, and Mr. Rastall) were elected at the last Anniversary Meeting, and Professor Penfield has since been added to the list of Honorary Members.

The total number of Members (on November 14, 1904) is 122; of these nineteen are Honorary, and 103 Ordinary Members; of the latter fifty are Life-Members, and fifty-three are Annual Subscribers.

Four Meetings have been held during the year, all in London and (by kind permission) in the Apartments of the Geological Society, Burlington House, London, W.

Two Numbers of the Journal, Nos. 62 and 63, published respectively in December, 1903, and October, 1904, have been issued; the former concludes Volume XIII, and has been provided with an index by Mr. Spencer; with the latter is a new List of Members (corresponding to September, 1904) and a reprint of the Bye-Laws as amended at the Anniversary Meeting of 1902. For the abstracts the Society is indebted to Mr. Spencer and Mr. Hutchinson.

The Council has to congratulate the Society on its continued prosperity.

On the motion of the President, seconded by Dr. Scott, the Report was adopted. A vote of thanks to the Geological Society for the permission to meet in its Apartments was carried with acclamation.

The newly-elected President, Professor Miers, having taken the Chair, the following papers were read:—

1. On some new forms of quartz-wedge and their uses: by Dr. J. W. Evans (p. 87).

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2. On an improved form of refractometer: by Mr. G. F. Herbert Smith (p. 83).

3. On the discovery of Bertrandite in Cornwall: by Mr. H. L. Bowman.

4. On Marrite, Lengenbachite, and Bowmanite, three new minerals from the Binnenthal: by Mr. R. H. Solly (p. 76).

5. On some curious crystals of Blende: by Mr. R. H. Solly (p. 81).

6. Note on some new localities for Gyrolite and Tobermorite: by Mr. James Currie (p. 93).

7. Note on the occurrence of Brookite in the Cleveland ironstone: by Mr. C. R. Lindsey (p. 96).

8. The construction of crystallographic projections: by Mr. Harold Hilton (communicated by Professor Miers) (p. 99).

9. Some applications of the gnomonic projection to crystallography: by Mr. Harold Hilton (communicated by Professor Miers) (p. 104).

In addition to specimens illustrative of the papers, Mr. Arthur Russell exhibited a large specimen of 'babel-quartz' which he had found at Great Work mine, Breage, Cornwall.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, January 31, 1905.

Professor H. A. Miers, D.Sc., F.R.S., President, in the Chair.

Dr. Wilbert Goodchild was elected an Ordinary Member of the Society.

Mr. H. F. Collins and Mr. B. Kitto were appointed to audit the accounts of the Society.

GENERAL MEETING.

Held in the Apartments of the Geological Society, January 31, 1905.

Professor H. A. Miers, D.Sc., F.R.S., President, in the Chair.

Twenty-two Members and four Visitors were present.

The election of Dr. Wilbert Goodchild to the Ordinary Membership of the Society was confirmed.

The following papers were read:—

1. On Danalite from Cornwall: by Professor H. A. Miers.

2. Crystallographic characters of barium-radium bromide: by Professor H. A. Miers.

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3. On an Epidote from Inverness-shire: by Mr. H. H. Thomas (p. 109).

4. On the regular growth of crystals of one substance upon those of another: by Mr. T. V. Barker.

5. Apparatus for determining the density of small grains: by Mr. K. A. K. Hallowes (communicated by Dr. J. W. Evans).

In addition to specimens illustrative of the papers, Mr. Arthur Russell exhibited a specimen of phenakite and one of aurichalcite from Cornish localities, and Mr. H. F. Collins specimens of sulphide of lead and oxide of zinc, artificially produced at Laurium.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, March 15, 1905.

Professor H. A. Miers, D.Sc., F.R.S., President, in the Chair.

The Secretary reported that Mr. L. J. Spencer had sent in to the Central Bureau of the International Catalogue of Scientific Literature 451 slips relative to titles of mineralogical and crystallographical papers published in the United Kingdom during the year 1904.

The Editorial Committee appointed on March 25, 1902, was re-appointed, Professor Miers and Dr. Müller interchanging places.

GENERAL MEETING.

Held in the Apartments of the Geological Society, March 15, 1905.

Professor H. A. Miers, D.Sc., F.R.S., President, in the Chair.

Twenty-two Members and one Visitor were present.

The following papers were read:—

1. Description of the big Diamond recently found at the Premier Mine, Transvaal: by Dr. F. H. Hatch and Dr. G. S. Corstorphine (communicated by the President).

2. On some new mineral localities in Cornwall and Devon: by Mr. Arthur Russell.

3. On a crystal of Phenakite from German East Africa: by Mr. L. J. Spencer.

4. Notes on various minerals from the Binnenthal, Switzerland: by Mr. G. T. Prior and Mr. G. F. Herbert Smith.

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5. On a new oxychloride of copper from Sierra Gorda, Chili: by the same.

6. On Dundasite from Wales: by Mr. G. T. Prior.

Dr. Hatch exhibited a model and lantern-slides in illustration of his paper, and the President exhibited lantern-slides relating to the Premier and Kimberley Diamond Mines.

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MINERALOGICAL SOCIETY.

ABSTRACT OF RECEIPTS AND PAYMENTS FROM JANUARY 1 TO DECEMBER 31, 1904.

Receipts.	£ s. d.	£ s. d.
Balance from 1903		55 4 1
Subscriptions—(1) current	47 4 0	
(2) arrears	12 8 6	
(3) in advance	2 2 0	
		61 9 6
Entrance fees and compositions		23 2 0
Sale of publications by publishers (1903)	12 16 0	
Do. by G. Savigar (1903)	0 11 7	
		13 7 7
Dividends on Stock		15 2 6
		£168 5 8

Payments.	£ s. d.	£ s. d.
Printing Magazine (No. 62)	89 19 4	
Authors' separate copies	5 3 9	
Illustrations	4 11 6	
		49 14 7
Miscellaneous Printing		4 14 10
Editor's Honorarium (1903)		10 10 0
International Catalogue slips		0 7 10
G. Savigar for care of Stock		1 1 0
Postage and Parcels		3 0 4
Porter's Fee		1 0 0
Bank Charges		1 0
Investments		15 2 6
Balance at Bank	81 0 10	
„ in Office	1 12 9	
		82 13 7
		£168 5 8

Examined and compared with the vouchers, and found correct. (*Signed*) BENEDICT KITTO, HENRY F. COLLINS } Auditors.

Liabilities.	£ s. d.	Assets.	£ s. d.
Owing for Printing, &c., of No. 63 of Magazine	38 2 8	Balance at Bank	81 0 10
„ Editor's Honorarium (1904)	10 10 0	„ in Office	1 12 9
„ Miscellaneous Printing	5 3 7	Consols (£646 8s. 10d., valued at £88)	569 1 10
„ G. Savigar for care of Stock (1904)	1 1 0	Balance owing from Publishers	24 12 6
„ Do. for postage	0 6 9	„ „ „ G. Savigar	0 15 4
„ Secretary's postage (1904)	1 6 11	Subscriptions in arrear, valued at	5 5 0
„ Treasurer's „ (1904)	0 8 9		
Excess of assets over liabilities	625 8 7		
	£682 8 8		£682 8 8

The number of Life-Members on December 31, 1904, was 51.

The Stock of Publications and the value of the Library are not included in the above assets.

(*Signed*) W. P. BEALE,
Hon. Treasurer.

February, 1905.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, June 14, 1905.

Professor H. A. Miers, D.Sc., F.R.S., President, in the Chair.

A letter of resignation of Membership of Mr. W. W. Butler was read.

Mr. De Castro, Dr. Flett, Mr. Rudler, and Dr. Tutton were nominated to replace the Ordinary Members of Council retiring by seniority, namely Messrs. Harker, Pollard, Prior, and Herbert Smith.

GENERAL MEETING.

Held in the Apartments of the Geological Society, June 14, 1905.

Professor H. A. Miers, D.Sc., F.R.S., President, in the Chair.

Eighteen Members were present.

The following papers were read:—

1. The chemical composition of Lengenbachite: by Mr. A. Hutchinson.
2. The chemical composition of Hutchinsonite: by Dr. G. T. Prior.
3. The identity of the ancient Amiantos of Cyprus with Chrysotile: by Dr. J. W. Evans (p. 143).
4. The application of methods of descriptive geometry to the gnomonic projection of crystals: by the same (p. 149).

Mr. D. F. Campbell showed a specimen of Dundasite from Wales (p. 167), and the President three sealed tubes containing supersaturated solutions of sodium nitrate which, however much shaken, deposit no crystals until cooled below certain temperatures (p. 123).

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, November 14, 1905.

Professor H. A. Miers, D.Sc., F.R.S., President, in the Chair.

Mr. Bernard Mouat Jones was elected an Ordinary Member of the Society, and Professor H. Baumhauer of Freiburg, Switzerland, an Honorary Member.

The following were selected as the dates of Meeting for the year 1906:—Tuesdays, January 23, March 20, June 12, November 13, the last to be the Anniversary Meeting.

The draft annual report of Council submitted by the Secretary was approved.

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ANNIVERSARY MEETING.

Held in the Apartments of the Geological Society, November 14, 1905.

Professor H. A. Miers, D.Sc., F.R.S., President, in the Chair.

Twenty-five Members and one Visitor were present.

The election of Mr. B. M. Jones as Ordinary Member and of Professor H. Baumhauer as Honorary Member was confirmed.

The scrutineers reported that thirty-five voting papers for the election of Officers and Council had been returned to the General Secretary, and that the List as nominated by the Council was approved, namely:—

President. Prof. H. A. Miers, M.A., D.Sc., F.R.S.

Vice-Presidents. Prof. W. J. Lewis, M.A., F.C.S.
Prof. G. D. Liveing, M.A., D.Sc., F.R.S.

Treasurer. W. Phipson Beale, K.C., F.G.S., F.C.S.

General Secretary. L. Fletcher, M.A., F.R.S.

Foreign Secretary. Prof. J. W. Judd, C.B., LL.D., F.R.S.

Editor of the Journal. L. J. Spencer, M.A., F.G.S.

Ordinary Members of Council.

H. L. Bowman, M.A., F.C.S.
H. F. Collins, A.R.S.M.
C. G. Cullis, D.Sc., F.G.S.
R. H. Solly, M.A.
J. W. Evans, LL.B., D.Sc., F.G.S.
Rev. J. M. Gordon, F.G.S.
J. A. Howe, B.Sc., F.G.S.
A. Hutchinson, M.A., F.G.S.
J. P. De Castro, M.A., F.C.S.
J. S. Flett, M.A., D.Sc., F.R.S.E.
F. W. Rudler, I.S.O., F.G.S.
A. E. H. Tutton, D.Sc., F.R.S.

The following Annual Report of Council was read:—

The Balance Sheet for the year ending December 31, 1904, which has already been published in No. 64 of the Journal, shows that the Assets of the Society (exclusive of the Library and the Stock of the Journal) amounted to £682 8*s.* 3*d.*, and that the Liabilities amounted to £56 19*s.* 8*d.* The number of Life-Members on December 31, 1904, was fifty-one; the value of the Stock invested in the names of the Trustees of the Society was on that date £569 1*s.* 10*d.*, corresponding to £11 3*s.* 2*d.* for each Life-Member.

During the Session 1904–5 the Society has lost no members either by death or resignation; three additional Ordinary Members (Mr. Barker,

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Mr. Woodgate, and Dr. Goodchild) have been elected. The total number of Members on November 13, 1905, was 123; of these nineteen are Honorary Members and 104 are Ordinary Members; of the latter fifty-one have compounded for the annual subscription.

Four Meetings have been held during the year, all in London, and (by kind permission) in the Apartments of the Geological Society, Burlington House.

Only one Number of the Journal, No. 64, published in May, 1905, has been issued during the Session. Three of the papers were descriptive of instruments; that of Mr. Hartley described a new device for separating minerals by means of heavy liquids; Mr. Herbert Smith's paper described an improved form of Refractometer; Dr. Evans explained some new forms of Quartz-wedge. Two papers of Mr. Hilton related to crystallographic projection; Mr. Solly described some new minerals from the Binnenthal; Mr. Currie and Mr. Thomas treated of Scotch Minerals, and Mr. Lindsey of Brookite from the Cleveland ironstone.

The Council has to congratulate the Society on its continued prosperity.

On the motion of the President, seconded by Dr. Scott, the Report was adopted.

A vote of thanks to the Council of the Geological Society for permission to meet in the Apartments of the Society was carried with acclamation.

The following papers were read:—

1. On a tabular crystal of white Diopside: by Prof. W. J. Lewis.

2. On a curious crystal of Pyroxene: by the same.

3. On a Carlsbad-twin of Albite: by the same.

4. The determination of the angle between the optic axes of a crystal in parallel polarized light: by Dr. J. W. Evans (p. 157).

5. Note on the formation of Gypsum crystals in a disused well at chemical works: by Mr. C. J. Woodward.

6. Note on the crystallization of drops, especially of potash-alum: Mr. Jacques Chevalier (communicated by the President) (p. 134).

7. On Ilmenite, Seligmannite, Marrite, Proustite, Trechmannite, and Hyalophane from the Binnenthal: by Mr. R. H. Solly (p. 184).

Specimens were exhibited in illustration of the various papers, and also a Turnerite from Switzerland by the Rev. J. M. Gordon, and Pitchblende from Cornwall by Mr. A. Russell.

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GENERAL MEETING.

Held in the Apartments of the Geological Society, January 23, 1906.

Professor H. A. Miers, D.Sc., F.R.S., President, in the Chair.

Eighteen Members and one Visitor were present.

The following papers were read:—

1. Geikielite and the magnesium-ilmenite series: by Mr. T. Crook and Mr. B. M. Jones (p. 160).

2. Studies in Crystallization: by Professor H. A. Miers and Mr. J. Chevalier (p. 123).

3. On the determination of refractive indices by the method of minimum deviation: by Mr. G. F. Herbert Smith (p. 191).

Dr. J. W. Evans afterwards initiated a discussion as to the indication of the character of quartz-wedges and mica-plates by means of marks on them. Professor Miers illustrated his paper by means of the lantern; Messrs. Crook and Jones showed specimens illustrating the characters of Geikielite; and Mr. Herbert Smith submitted a diagram (Plate IV) useful for the determination of refractive indices without calculation.

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EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, March 20, 1906.

Professor H. A. Miers, D.Sc., F.R.S., President, in the Chair.

The resignation of Mr. Herbert Stanley Jevons, Ordinary Member, and the death of Professor Vivant Léon Moissenet, Honorary Member, on February 2, 1906, were announced.

Mr. B. Kitto and Mr. J. P. De Castro were appointed auditors of the accounts for the year ending December 31, 1905.

Mr. L. J. Spencer reported that he had forwarded, on behalf of the Society, 539 slips relative to mineralogical and crystallographical papers and books, published in the United Kingdom during 1905, to the Central Bureau of the International Catalogue of Scientific Literature.

Resolved that a Council Meeting be held thirty minutes before each Ordinary Meeting, and be announced on the date-card of meetings for the year.

GENERAL MEETING.

Held in the Apartments of the Geological Society, March 20, 1906.

Professor H. A. Miers, D.Sc., F.R.S., President, in the Chair.

Twenty-four Members and one Visitor were present.

The following papers were read:—

1. On the occurrence of Caledonite and Linarite in County Wicklow: by Mr. Arthur Russell.

2. On the parallel growth of salts on minerals: by Mr. T. V. Barker.

In addition to specimens shown by authors in illustration of their papers, the following specimens were exhibited: by Dr. J. W. Evans, twin-crystals of Thorianite; by Mr. F. N. A. Fleischmann, various Zeolites; by Mr. L. Fletcher, a Brazilian Euclase and Japanese Chalcopyrite and Danburite; by Mr. A. Hutchinson, a remarkable crystal of Calcite from Kimberley, South Africa; by Mr. Arthur Russell, crystals of Brookite recently collected by him at Tremadoc.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, June 12, 1906.

Professor H. A. Miers, D.Sc., F.R.S., President, in the Chair.

An application from the Imperial Institute, London, for exchange of publication was approved.

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Resolved to nominate Professor W. W. Watts as Foreign Secretary, in place of Professor J. W. Judd retiring, and Mr. J. J. Beringer, Mr. Harold Hartley, Dr. G. T. Prior, Dr. A. P. Young in place of the four retiring Members of Council (Messrs. H. L. Bowman, H. F. Collins, C. G. Cullis and R. H. Solly).

The audited Balance Sheet for the year ending December 31, 1905, was submitted and approved.

GENERAL MEETING.

Held in the Apartments of the Geological Society, June 12, 1906.

Professor H. A. Miers, D.Sc., F.R.S., President, in the Chair.

Seventeen Members and one Visitor were present.

The following papers were read:—

1. A pseudomorph of Quartz after Apophyllite from the Val Sumela, Fassathal: by Mr. Harold Hartley and Mr. Noel G. Thomas.

2. A heating-stage for the Dick microscope: by Mr. Harold Hartley.

3. The occurrence of Axinite in the area south of Bodmin in Cornwall: by Mr. George Barrow.

4. Cassiterite pseudomorphs from Bolivia: by Mr. Richard Pearce.

5. Notes on Skiodroms and Isogyres: by Dr. J. W. Evans (p. 230).

6. Crystallography of Sartorite from Binn: by Dr. C. O. Trechmann (p. 212).

In addition to specimens shown by authors in illustration of their papers, the following specimens were exhibited: by Mr. J. P. De Castro, a fine crystal of Tantalite from Western Australia; by Mr. L. Fletcher, two specimens of Cornish elvan, one showing a loose nodule of graphite and the other a loose pebble; by Mr. R. Pearce, Axinite from St. Ives, Cornwall.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, November 13, 1906.

Professor H. A. Miers, D.Sc., F.R.S., President, in the Chair.

Mr. George Stanfield Blake was elected an Ordinary Member of the Society.

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The following were selected as the dates of Meeting for the year 1907:—Tuesdays, January 29, March 19, June 11, November 12, the last to be the Anniversary Meeting.

The draft annual report of Council, submitted on behalf of the General Secretary, was approved.

The announcement was made of the deaths of Professor Penfield, Honorary Member, and Mr. R. P. Greg, formerly Ordinary Member and Treasurer.

ANNIVERSARY MEETING.

Held in the Apartments of the Geological Society, November 13, 1906.

PROFESSOR H. A. MIERS, D.Sc., F.R.S., President, in the Chair.

Twenty-five Members were present.

The election of Mr. G. S. Blake to the Ordinary Membership was confirmed.

The scrutineers reported that thirty-eight voting papers for the election of Officers and Council had been returned, and that the List as nominated by the Council was approved, namely:—

President. Prof. H. A. MIERS, M.A., D.Sc., F.R.S.

Vice-Presidents. Prof. W. J. LEWIS, M.A., F.C.S.
Prof. G. D. LIVEING, M.A., D.Sc., F.R.S.

Treasurer. W. PHIPSON BEALE, K.C., M.P., F.G.S., F.C.S.

General Secretary. L. FLETCHER, M.A., F.R.S.

Foreign Secretary. Prof. W. W. WATTS, M.A., F.R.S.

Editor of the Journal. L. J. SPENCER, M.A., F.G.S.

Ordinary Members of Council.

J. W. EVANS, LL.B., D.Sc., F.G.S.
Rev. J. M. GORDON, F.G.S.
J. A. HOWE, B.Sc., F.G.S.
A. HUTCHINSON, M.A., F.G.S.
J. P. DE CASTRO, M.A., F.C.S.
J. S. FLETT, M.A., D.Sc., F.R.S.E.
F. W. RUDLER, I.S.O., F.G.S.
A. E. H. TUTTON, D.Sc., F.R.S.
J. J. BERINGER, A.R.S.M., F.C.S.
H. B. HARTLEY, M.A., F.C.S.
G. T. PRIOR, M.A., D.Sc., F.G.S.
A. P. YOUNG, Ph.D., F.G.S.

The following ANNUAL REPORT OF COUNCIL was read:—

The Balance Sheet for the year ending December 31, 1905, shows that the Assets of the Society (exclusive of the Library and the Stock of the

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Journal) amounted to £690 8*s.* 5*d.*, and that the Liabilities amounted to £17 2*s.* 10*d.* The number of Life-Members on December 31, 1905, was fifty-one; the value of the Stock invested in the names of the Trustees of the Society was on that date £612 12*s.* 8*d.*, corresponding to £12 0*s.* 3*d.* for each Life-Member.

During the Session 1905–6 the Society has lost one Ordinary Member by resignation (Mr. Jevons), and two Honorary Members by death (Professors Penfield and Moissenet); one Ordinary Member (Mr. Jones) and one Honorary Member (Professor Baumhauer) have been elected. The total number of Members on November 12, 1906, was 123, of these nineteen are Honorary Members and 104 are Ordinary Members; of the latter fifty-one have compounded for their annual subscription.

Four Meetings have been held during the year, all in London, and (by kind permission) in the apartments of the Geological Society, Burlington House.

Only one number of the Journal, No. 65, published in May, 1906, has been issued during the Session. Papers by Professor Miers and Mr. Chevalier dealt with the crystallization of salts from solutions in the metastable and labile conditions; Dr. Evans contributed papers on gnomonic projection, the determination of optic axial angles, and the identity of the amiantos of the ancients with chrysotile; Messrs. Crook and Jones discussed the chemical composition of the ferromagnesian titanates; Dr. Prior described dundasite from Wales; Mr. Herbert Smith discussed a method for the determination of refractive indices, and described a new mineral, paratacamite; Mr. Spencer gave an account of phenacite and other minerals from German East Africa; and Mr. Solly contributed further notes on minerals from the Binnenthal.

The Council has to congratulate the Society on its continued prosperity.

On the motion of Mr. Hutchinson, seconded by Mr. Bowman, the Report was adopted.

Announcement was made of the deaths of Professor Penfield and Mr. R. P. Greg.

The dates of Meeting for the year 1907, proposed by the Council, were approved.

A vote of thanks to the Council of the Geological Society for permission to meet in the Apartments of the Society was carried with acclamation.

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The following papers were read:—

1. Growth of crystals of soluble salts on each other: by Mr. T. V. Barker (p. 235).

2. Notes on some Bolivian Minerals: by Mr. L. J. Spencer.

3. Note on Ilmenite from Brazil: by Mr. G. F. Herbert Smith (p. 258).

4. Description of the Lengenbach quarry and of the minerals found there in 1906: by Mr. R. H. Solly.

5. Note on the thirty-two classes of symmetry: by Mr. H. Hilton (p. 261).

Lantern-slides were shown by Mr. Barker in illustration of his paper. Specimens of Monazite from Cornwall and Harmotome from Co. Wicklow were exhibited by Mr. A. Russell; and crystals of Sartorite by Dr. C. O. Trechmann.

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MINERALOGICAL SOCIETY.

ABSTRACT OF RECEIPTS AND PAYMENTS FROM JANUARY 1 TO DECEMBER 31, 1905.

Receipts.	£ s. d.	£ s. d.
Balance from 1904		82 13 7
Subscriptions—(1) current	45 3 0	
(2) arrears	2 2 0	
		47 5 0
Entrance fees		2 2 0
Sale of publications by publishers (1904)	24 12 6	
Do. by G. Savigar (1904)	0 15 4	
		25 7 10
Dividends on Stock		15 12 0
		£173 0 5

Payments.	£ s. d.	£ s. d.
Printing Magazine (No. 63)	27 16 8	
Authors' separate copies	4 11 0	
Illustrations	4 5 0	
		36 12 8
Printing Magazine (No. 64)	19 1 4	
Authors' separate copies	3 19 6	
Illustrations	2 5 0	
		25 5 10
Miscellaneous Printing		6 12 7
Binding		7 10 0
Editor's Honorarium (1904)		10 10 0
G. Savigar for care of Stock		1 1 0
Postage and Parcels (including postage on Magazine)		4 16 11
Porter's Fee		1 0 0
Bank Charges		0 1 0
Investments		81 7 0
Balance at Bank	45 17 5	
„ in Office	2 6 0	
		48 3 5
		£173 0 5

Examined and compared with the vouchers, and found correct.

(*Signed*) BENEDICT KITTO
J. PAUL DE CASTRO } Auditors.

Liabilities.	£ s. d.	Assets.	£ s. d.	£ s. d.
Owing for Editor's Honorarium (1905)	10 10 0	Balance at Bank		45 17 5
„ Miscellaneous Printing	8 16 0	„ in Office		2 6 0
„ G. Savigar for care of Stock (1905)	1 1 0	Consols (£680 14*s.* 8*d.*, valued at £90)		612 12 8
„ Do. for postage (1905)	0 4 0	Sale of publications—		
„ Secretary for fee to Porter (advanced)	0 10 0	Balance owing from Publishers	17 12 6	
„ „ „ postage (1905)	0 15 0	„ „ „ G. Savigar	5 8 10	
„ Treasurer „ „ (1905)	0 6 10			23 1 4
Excess of assets over liabilities	678 0 7	Subscriptions in arrear, valued at		6 6 0
	£690 8 5			£690 8 5

The number of Life-Members on December 31, 1905, was 51.

The Stock of Publications and the value of the Library [illegible]

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, January 29, 1907.

PROFESSOR H. A. MIERS, D.Sc., F.R.S., President, in the Chair.

Dr. James B. Mears and Mr. Thomas Crook were elected Ordinary Members of the Society.

Mr. H. L. Bowman and Dr. A. P. Young were appointed auditors of the accounts for the year ending December 31, 1906.

GENERAL MEETING.

Held in the Apartments of the Geological Society, January 29, 1907.

PROFESSOR H. A. MIERS, D.Sc., F.R.S., President, in the Chair.

Twenty-two Members and four Visitors were present.

The elections of Dr. J. B. Mears and of Mr. T. Crook to the Ordinary Membership of the Society were confirmed.

The following papers were read:—

1. Experiments bearing on the order of crystallization of rock-constituents: by Professor H. A. Miers.

2. Serpentine-rock from the Tarnthaler-Köpfe, Tirol: by Dr. A. P. Young (p. 365).

3. A simple tabular arrangement of the thirty-two crystallographic classes: by Dr. J. W. Evans (p. 360).

4. A refractometer for use with mounted precious stones: by Dr. G. F. Herbert Smith (p. 354).

5. Isomorphism as illustrated by certain varieties of Magnetite: by Professor B. J. Harrington (p. 373).

A collection of Japanese Zeolites was exhibited by Mr. F. N. A. Fleischmann; an objective giving a flat field with convergent light by Dr. J. W. Evans; and an instrument for the determination of the refractive indices of solutions by Professor Miers.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, March 19, 1907.

PROFESSOR H. A. MIERS, D.Sc., F.R.S., President, in the Chair.

Mr. John Parkinson, B.A., F.G.S., was elected an Ordinary Member of the Society.

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Mr. L. J. Spencer reported that he had forwarded, on behalf of the Society, 947 slips relative to mineralogical, crystallographic, and petrological papers and books, published in the United Kingdom during 1906, to the Central Bureau of the International Catalogue of Scientific Literature.

GENERAL MEETING.

Held in the Apartments of the Geological Society, March 19, 1907.

Professor H. A. Miers, D.Sc., F.R.S., President, in the Chair.

Nineteen Members were present.

The election of Mr. John Parkinson to the Ordinary Membership was confirmed.

The following papers were read:—

1. On the silver deposit in the Perran mine, Perran Uthnoe, Cornwall: by Mr. F. H. Butler (p. 385).

2. On the minerals of the Silvermines district, Co. Tipperary: by Mr. Arthur Russell (p. 350).

3. On Baddeleyite from Ceylon: by Mr. G. S. Blake and Dr. G. F. Herbert Smith (p. 378).

4. Zinciferous Tennantite from the Binnenthal: by Mr. R. H. Solly and Dr. G. T. Prior.

5. On Strüverite, a new mineral: by Dr. F. Zambonini and Dr. G. T. Prior.

Specimens were exhibited by Mr. Butler and Mr. Russell in illustration of their papers.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, June 11, 1907.

Professor H. A. Miers, D.Sc., F.R.S., President, in the Chair.

The audited Balance Sheet for the year ending December 31, 1906, was submitted and approved.

Resolved to nominate Mr. W. Barlow, Mr. B. Kitto, Mr. Arthur Russell, and Dr. G. F. Herbert Smith in place of the four retiring Members of Council (Messrs. Evans, Gordon, Howe, and Hutchinson).

Mr. Harold Hilton was elected an Ordinary Member of the Society.

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The President was appointed as Delegate to attend the Centenary Celebration of the Geological Society.

The announcement was made of the death of Mr. J. F. Walker on May 23, 1907.

GENERAL MEETING.

Held in the Apartments of the Geological Society, June 11, 1907.

Professor H. A. Miers, D.Sc., F.R.S., President, in the Chair.

Seventeen Members and two Visitors were present.

The election of Mr. Harold Hilton to the Ordinary Membership was confirmed.

The following papers were read:—

1. Hamlinite from the Binnenthal: by Mr. H. L. Bowman (p. 389).
2. Note on faceted beads of Zinc: by Mr. T. V. Barker.
3. On Chlormanganokalite: by Dr. H. J. Johnston-Lavis and Mr. L. J. Spencer.

Fine crystals of Hopeite, Cerussite, &c., from the Rhodesia Broken Hill mines, North Western Rhodesia, were exhibited by Mr. L. J. Spencer; a large clear crystal of Apatite from Switzerland was shown by Mr. J. M. Gordon; and a group of Quartz-crystals from British Guiana by Mr. C. W. Anderson.

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ABSTRACT OF RECEIPTS AND PAYMENTS FROM JANUARY 1 TO DECEMBER 31, 1906.

Receipts.	£ s. d.	£ s. d.
Balance from 1905		48 3 5
Subscriptions—(1) current	42 0 6	
(2) arrears	11 11 0	
		53 11 6
Sale of publications by G. Savigar (1905)		5 8 10
Dividends on Stock		16 6 6
		£123 10 3

Payments.	£ s. d.	£ s. d.
Printing Magazine (No. 65)	23 16 6	
Authors' separate copies	5 6 3	
Illustrations	3 9 0	
		32 11 9
Miscellaneous Printing		5 7 0
Editor's Honorarium (1905)		10 10 0
G. Savigar for care of Stock		1 1 0
Porter's Fee		1 0 0
Postage and Parcels—		
Printers (Magazine)	1 15 7	
,, (Authors' copies)	2 9	
G. Savigar	4 0	
Hon. Secretary	15 0	
Hon. Treasurer	6 10	
		3 4 2
Investments		16 6 6
Bank Charges		0 0 9
Balance at Bank	49 17 5	
,, in Office	3 11 8	
		53 9 1
		£123 10 8

Examined and compared with the vouchers, and found correct.

(*Signed*) A. P. YOUNG, H. L. BOWMAN } Auditors.

Liabilities.	£ s. d.
Owing for Editor's Honorarium (1906)	10 10 0
,, Miscellaneous Printing	2 17 2
,, G. Savigar for care of Stock (1906)	1 1 0
,, Do. for postage (1906)	0 2 11
,, Hon. Secretary for postage (1906)	0 11 0
,, Hon. Treasurer ,, ,, (1906)	0 6 3
Excess of assets over liabilities	692 3 9
	£707 12 1

Assets.	£ s. d.	£ s. d.
Balance at Bank		49 17 5
,, in Office		3 11 8
Consols (£698 18*s.* 3*d.*, valued at £86)		601 1 3
Balance due from Publishers (1905)	17 12 6	
,, ,, ,, (1906)	17 3 0	
,, ,, G. Savigar (1906)	5 14 3	
		40 9 9
Subscriptions in arrear, valued at		12 12 0
		£707 12 1

The number of Life-Members on December 31, 1906, was 51.

The Stock of Publications and the value of the Library are not included in the above assets.

(*Signed*) W. P. BEALE.

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